National Aeronautics and Space Administration

Headquarters
Washington, DC 20546-0001

Office of the Chief Technologist

March 15, 2011

Reply to Attn of:

Mr. Edsel M. Brown, Jr.
Assistant Administrator, Office of Technology
U.S. Small Business Administration
409 Third Street, SW
Washington, DC 20416

Dear Mr. Brown:

Enclosed please find the National Aeronautics and Space Administration (NASA) Small Business Innovation Research (SBIR) Program's response to your 2010 request and guidance for providing data in response to Executive Order 13329, "Encouraging Innovation in Manufacturing."

In response to SBA's data request on E.O. 13329, enclosed please find a spreadsheet containing the new SBIR and STTR awards in FY 2010 (FY 2009-I, FY 2008-II), which references manufacturing in the technical abstract. The following chart reflects funding selections for SBIR and STTR awards.

Program	PY	Awards	Phase III
SBIR	2009-I	37	
SBIR	2008-II	24	
SBIR			1
STTR	2009-1	8	
STTR	2008-II	2	

Also included is a sample of manufacturing-based firm articles from *Spinoff*, NASA's annual premier publication featuring successfully commercialized NASA technology.

NASA continues to fully support E.O. 13329 to ensure that our SBIR & STTR programs advance manufacturing research and development as set forth in its direction. The NASA SBIR/STTR programs still view manufacturing and energy areas as priorities for tiebreakers in selection but, did not selected any of the listed awards on that basis.

Please call me at (202) 358-4658 if any additional information is desired.

Sincerely,

Carl G. Ray
SBIR/STTR Program Executive

Enclosures:
1. Active SBIR/STTR Phase I and Phase II Awards from 2010
2. SBIR Phase III Energy Program Results from 2010
3. Sample Spinoff 2010

cc:
OCT/Dr. Braun
Mr. Gazarik
Mr. Schingler
Mr. Parrish
Mr. Battaglia
Ms. Brooks
ARC/202-206/Dr. Jahns

Program	Program Year	Phase	Proposal#	Contract#	Firm Name	Proposal Title	Award Amount	Proposal Abstract
SBIR	09	1	O1.04-9344	NNX10CE30P	AlphaSense, Inc.	RF Front End Based on MEMS Components for Miniaturized Digital EVA Radio	$99,970.00	In this proposal, AlphaSense, Inc. (AI) and the Carnegie Mellon University (CMU) detail the development of RF front end based on MEMS components for miniaturized digital EVA radio. Key innovations of our approach include: a) the use of a novel parallel receiver front end architecture based on MEMS components, b) a novel design of a high Q mixer-filter for RF mixing and IF filtering, and c) the implementation of band pass filter and voltage controlled oscillator (VCO) using CMOS fabrication technique. Consequently, the proposed EVA radio has the following merits: a)Small size, light- weight and low power consumption, b)High sensitivity and frequency selectivity, c)Good device reliability, and d)Easy device fabrication and low **manufacturing** cost.
SBIR	09	1	S3.05-8550	NNX10CD11P	APECOR	High-Temperature, Wirebondless, Ultra-Compact Wide Bandgap Power Semiconductor Modules for Space Power Systems	$99,738.00	Silicon carbide (SiC) and other wide band-gap semiconductors offer great promise of high power rating, high operating temperature, simple thermal management, and ultra-high power density for both space and commercial power electronic systems. However, this great potential is seriously limited by the lack of reliable high temperature device packaging technology. The objective of this proposed research is to develop a ultra-compact, hybrid power module packaging technology based on the use of double leadframes and direct leadframe-to-chip transient liquid phase (TLP) bonding that allows device operation up to 450^oC. The Phase I research plan will include: 1) material selection; 2) electrical, mechanical, and thermal design of a half-bridge prototype module; 3) packaging process development using volume **manufacturing** processes; 4) stress and thermal modeling and analysis; 5) material characterization under high temperature and high temperature cycling; and 6) cost estimation and comparative analysis with competing technologies. The unique advantages of this innovative solution include very high current carrying capability, low package parasitic impedance, low thermo-mechanical stress at high temperatures, double-side cooling, and modularity for easy system-level integration. The new power module will have a very small form factor with 3-5X reduction in size and weight from the prior art.

SBIR	09	1	X5.03-9388	NNX10CF32P	Applied Poleramic	Long Out-time, Out-of-Autoclave Cure Composites	$99,248.00	As the size of composite parts exceed that of even the largest autoclaves, new out-of-autoclave processes and materials are necessary to achieve the same level of performance as autoclave cured composites. Unfortunately, the quality of composites **manufactured** with current out-of-autoclave prepreg systems is limited by their short shelf-life at ambient conditions. The resin advancement, due to long lay-up times, commonly causes variations in fiber volume and higher void content in the cured structures. Also, current out-of-autoclave prepreg systems do not provide the same level of performance, especially damage tolerance, as many current autoclave cured prepreg systems. It is the objective of this work to develop a matrix and prepreg system for out-of-autoclave processing that has a year out-time at ambient conditions while also providing an excellent balance of mechanical properties and damage tolerance. As an additional functionality, the out-of-autoclave prepreg system will be developed to have inherent skin-core self-adhesive properties so that film adhesives are not required for designs with honeycomb cores. It is expected that the TRL will be 4 at the end of this Phase I program.
SBIR	09	1	O1.03-8382	NNX10CC60P	Aries Design Automation, LLC	Reconfigurable VLIW Processor for Software Defined Radio	$100,000.00	We will design and formally verify a VLIW processor that is radiation-hardened, and where the VLIW instructions consist of predicated RISC instructions from the PowerPC 750 Instruction Set Architecture (ISA). The PowerPC 750 ISA is used in the radiation-hardened RAD750 flight-control computer that is utilized in many NASA space missions, including Deep Impact, the Mars Reconnaissance Orbiter, the Mars Rovers, and is planned to be used in the Crew Exploration Vehicle (CEV). The VLIW processor will have reconfigurable functional units and specialized instructions that will be optimized for Software Defined Radio applications. The radiation-hardening will be done at the microarchitectural level with a mechanism that will allow the detection and correction of all timing errors---caused not only by radiation, but also by variations in the voltage, frequency, **manufacturing** process, and aging of the chip. The binary-code compatibility of the resulting VLIW processors with the PowerPC 750 ISA will allow them to seamlessly execute legacy binary code from previous space missions. We have made critical contributions to the fields of formal verification of complex pipelined microprocessors, and Boolean Satisfiability (SAT), and have developed highly efficient Electronic Design Automation (EDA) tools that we will use.

SBIR	09	1	S1.05-9730	NNX10CD59P	Arradiance, Inc.	Functionalized Nano-Film Microchannel Plate: A Single High Aspect Ratio Device for High Resolution, Low Noise Astronomical Imaging	$99,660.00	The proposed innovation is to apply proven nano-film technology to enable Microchannel plate (MCP) devices to be **manufactured** on a range of insulating substrates and devices which possess sufficiently high gain and low ion feedback to replace chevron stacks in current NASA detector technologies. Commercial MCP devices have many desirable properties, such as sensitivity to small amounts of light and excellent position and timing resolution. MCP production is a mature technology, based largely on techniques and materials developed in the 1970's, and is limited to small area devices. Limitations due to the bulk glass **manufacturing** technology adversely impact many applications and impair **manufacturability**. For example, heavy metal impurities contained within the bulk glass of the MCP limit the achievable dark noise in low signal detection. In MCP **manufacturing**, the requisite batch processing restricts flexibility to tailor individual device or small batch performance to specific applications and can often result in poor MCP yield due to variations in composition and poor process control. In this proposal, we will utilize atomic layer deposition (ALD) of nanometer thin films which has been proven to replicate and improve the component functions of secondary electron emission (SEE) and conductivity on non-traditional glass substrates, to investigate the high gain and low ion feedback capabilities of this technology. We estimate that the technology stands at TRL 2 at the and expect to be at 4 at end of the Phase 1 contract.

SBIR	09	1	A4.01-8257	NNX10CE87P	Baker-Calling, Inc	Piezoelectric MEMS Microphones for Ground Testing of Aeronautical Systems	$60,708.00	Improving the acoustical environment is critical in aeronautics. Airports and aeronautical systems **manufacturers** are facing ever-increasing demands to red

SBIR	09	1	O2.02-8697	NNX10CF36P	Blue Ridge Research and Consulting	System for Acquisition and Analysis of Energy-Based Acoustic Data for Rocket Noise	$99,683.00	Accurate estimates of the vibroacoustic loading placed on space vehicles and payloads during launch require knowledge of the rocket noise source properties. Given the extreme nature of acoustic environments near the plume, data sufficient to characterize the noise source region have been difficult to acquire. Without these data, structures may be designed to handle an insufficient or excessive vibroacoustic loads, resulting in either an overbuilt structure (and extra weight), or an under-designed vibration isolation system that could result in damaged cargos. Current energy base acoustic probe designs have limited frequency bandwidth due to physical limitations. A new set of probe designs is proposed that incorporate both a new physical probe design but also a more advanced signal processing methodology that will significantly increase the usable frequency bandwidth of the probes while reducing the **manufacturing** and maintenance costs of the probes. The probe system will also include the design of a complete data acquisition system capable of recording data under the harsh conditions present in typical rocket motor test firings.
SBIR	09	1	S2.02-9231	NNX10CE09P	Boston Micromachines Corporation	Enhanced Fabrication Processes Development for High Actuator Count Deformable Mirrors	$99,918.00	It is proposed to advance **manufacturing** science and technology to improve yield and optical surface figure in high actuator count, high-resolution deformable mirrors (DM) required for wavefront control in space-based high contrast imaging instruments. As the scale of batch fabricated, polysilicon surface micromachined MEMS DMs increases to thousands of actuators the associated increase in devices size limits the achievable yield due to micro-scale defects introduced during the **manufacturing** processes and large unpowered surface figure errors. In Phase I research, major obstacles preventing scalability of microfabrication processes to large arrays will be overcome by developing a polysilicon deposition process to reduce and control defect density to maximize the yield of a 1027 segment Tip-Tilt Piston DM with 3081 actuators and to determine the practical limits of the tool set and compatibility of this process for the **manufacture** of MEMS DMs with >104 actuators. **Manufacturing** processes to minimize unpowered surface figure errors will be developed to (1) reduce substrate curvature induced DM surface figure errors through control of deposition and polishing processes to balance the front and backside film thickness, and (2) reduce polishing induced DM surface figure errors by modifying the device wire routing layout design to maintain uniform pattern density across the device area to achieve uniform material removal rates in the polishing process. Successful completion of the Phase 1 work will enable the design and **manufacture** of a 1027 Tip-Tilt-Piston deformable mirror required for NASA's visible nulling coronagraph instrument in a Phase 2 effort.

SBIR	09	1	X10.01-8831	NNX10CD16P	Carbon-Carbon Advanced Technologies, Inc.	Carbon-Carbon High Melt Coating for Nozzle and Nozzle Extensions	$99,366.00	C-CAT, which has proven carbon-carbon fabrication capabilities, will investigate use of ACC-6 High Melt oxidation protective system on carbon-carbon for use on the Cryogenic and Non-Toxic Storable Propellant Space Engine nozzle and nozzle extensions. ACC-6 High Melt is a carbon-carbon coating application that embeds HfC,ZrB2 in the outer layers. This material system has been tested in Arc Jet environment at over 3000 degrees F, for more than 24 minutes with little to no erosion. ACC-6 High Melt has shown to be the best performing high temperature material system, and still retains the ease of **manufacturing** associated with carbon-carbon. ACC-6 High Melt has been **manufactured** in small scale leading edge experiments, but has yet to be demonstrated in large components. **Manufacturability** of large scale components remains as the main question to be answered for this material system. For Phase I, C-CAT proposes to build subsections of a nozzle extension representing the attach flange and the exit diameter of approximately 40" diameter. Success will be achieved by **manufacturing** the aforementioned subsection using ACC-6 High Melt with no voids or spalling of coating. This successful demonstration will provide the path for scale-up to a full size prototype nozzle extension for Phase II.
SBIR	09	1	X5.03-9295	NNX10CF30P	Cornerstone Research Group, Inc.	SMP Bladder Tooling for Manufacturing Composites	$99,994.00	CRG's shape memory polymer (SMP) Bladder Tooling is a cutting-edge **manufacturing** technology that can meet the **manufacturing** needs of the Ares launch vehicles. This process provides labor savings, weight reductions, and reliable **manufacturing** results for fabricating complex composites. SMP bladder tooling eliminates the transferring process by operating as both a rigid lay-up mandrel and an elastic bladder. Initially, the tooling is a rigid, durable surface for composite lay-up, then when heated during the cure cycle the tooling transitions to a flexible bladder to provide consolidation force. The tooling can then be easily removed from the cured composite while in the elastic state, reformed, and reused for the next part. In addition to increased part quality, SMP bladder tooling can present a significant cost reduction over current **manufacturing** processes. When comparing SMP bladder tooling with a silicone bladder over a foam insert for **manufacturing** of an Environmental Control System (ECS) duct, there is a 46% savings over the first three parts and 80% savings over twelve parts. A second cost saving example is the comparison of SMP bladder tooling with washout tooling for the same ECS duct. Cost saving for the first three parts is 40% and 79% over twelve parts.

SBIR	09	1	X9.01-8952	NNX10CC52P	Fiber Materials, In	Phenolic Impregnated Carbon Ablator (PICA) Gap Filler for Heat Shield Assemblies	$99,149.00	During this program Fiber Materials, Inc. (FMI^{REG}) will develop practical methods for preparing Phenolic Impregnated Carbon Ablator (PICA) materials for joining thermal protection system (TPS) segments and penetrations of the heat shield assembly. Current and future mission flight environments and designs, such as those for Mars Science Laboratory Aeroshell (MSLA) and anticipated for New Frontiers and Mars EDL missions, will be assessed. Capability of developed solutions will address mechanical and thermal robustness, and surface recession under mission defined conditions. The Phase 1 program will evaluate joining and gap-fill materials, assess joining designs that can be cost effectively **manufactured** and assembled, define assembly methods and test joining material performance. The joining design and material approaches, test results, assembly methodology, and Phase 2 work plan will be delivered at the conclusion of the Phase I program. During the Phase 2 program, a mission scale PICA sub-assembly utilizing the developed joining system will be demonstrated, and representative assembly coupons will be tested under flight conditions. The proposed materials, designs and methods are TRL ¡Ü 3. It is anticipated that TRL ¡Ý 7 will be achieved at the conclusion of a successful Phase 1 and Phase 2 programs.
SBIR	09	1	S2.05-9809	NNX10CD73P	Hardric Laborator	Advanced Lightweight Metal Matrix Composite Segmented Optic Manufacture	$91,069.00	Design, **manufacture** and test a flat segmented mirror made of optical grade AlBeMet 162 material and fusion bonded through the use of E Beam welding to demonstrate the feasability of **manufacturing** much larger segmented optics that perform as monlithic optics.

SBIR	09	1	X5.03-9269	NNX10CF29P	Intelligent Optical Systems, Inc.	Fast Cure Repair Kit for Composites	$99,997.00	NASA has a need for technologies that will enable them to repair damage to composite structures. Fiber-reinforced polymer composite materials are fast gaining ground as preferred materials for the construction of aircraft and spacecraft. In particular, the use of composites as primary structural materials in several technology-demonstrator front-line aerospace projects worldwide has provided confidence leading to their acceptance as prime materials for aerospace vehicles. Respectively, materials and tools that can provide rapid, permanent or temporary repairs of composite structural damage in a space environment should follow the wide utilization of composites in airspace vehicles. This proposed project will result in the development of a fast cure repair kit for composites (C-kit) that will consist of the basic composite fabric preimpregnated (prepreg) with an ultraviolet (UV) light-curing resin, a dispenser containing UV curable resin with properties close to the basic matrix resin, and a battery-operated portable, efficient single light emitting diode (LED) as the source of UV radiation. The prepreg material, which will be in the form of tape and precut patches, and the resin will be stored separately in protective dispensers. The cure of each layer of repair material will take less than a minute. Surface cleaning materials will also be included in the kit. In this project, IOS will collaborate with a **manufacturer** devoted specifically to the development of UV cured adhesives for specific high end applications. This work will extend the knowledge and experience previously attained by the IOS/ SGL team in the development of light-curing adhesives for Navy ships corrosion protection and for corrosive barrier restoration in Navy fleet composite materials.
SBIR	09	1	A1.10-8501	NNX10RA70P	Invocon, Inc.	Surface-Borne Time-of-Reception Measurements (STORM)	$99,991.00	Invocon proposes the Surface-borne Time-Of-Reception Measurements (STORM) system as a method to locate the position of lightning strikes on aerospace vehicles. Initially developed as a hypervelocity impact location system, the baseline technology lends itself to simple adaptation for lightning location. It uses Time-Of-Arrival (TOA) measurements of the charge wave front imparted on a structure to triangulate the location of lightning attachment. Additional capability can be added to the triggering circuitry that will characterize the lightning strike in order to increase situational awareness for flight crews and provide maintenance crews with information vital to determine the health of an aircraft. This is particularly important for new airframes **manufactured** from composite materials that have not be fully characterized over the full lifetime of the aircraft.

SBIR	09	1	S3.08-8144	NNX10CF22P	Materials Research and Design	Refractory Coated/Lined Low Density Structures	$99,802.00	The innovation in this proposed effort is the development of refractory coated or lined low density structures. Lightweight structures are desirable for space transportation vehicle systems in order to reduce launch costs, increase mission flexibility/efficiency, and add robustness with respect to the ability to add weight or additional materials to the mission with minimum sacrifice in performance. The use of thin refractory coatings over low density structures will yield a lightweight alternative to current solid monolithic components. Thus, offering an increase in mission flexibility by allowing greater speeds, greater range, and bigger payloads. Additional studies will be conducted to seek materials that offer higher temperature use, lower weight, and lower cost. The higher maximum temperatures may eliminate the need for cooling air, while simultaneously increasing engine efficiency. These benefits result in increased fuel savings. The advanced materials study will include refractory metals and ceramics. The **manufacturing** processes for the monolithic ceramics and refractory metal materials will include vacuum plasma spraying (VPS) and EL-Form electrodeposition.

SBIR	09	1	A2.08-9364	NNX10CC79P	Michigan Engineering Services, LLC	Integrated Network of Optimizations for Aircraft Systems	$99,610.00	Aircraft design is a complex process requiring interactions and exchange of information among multiple disciplines such as aerodynamics, strength, fatigue, controls, propulsion, corrosion, maintenance, and **manufacturing**. A lot of attention has been paid during the past fifteen years in the Multi-disciplinary Design Optimization (MDO) nature of the aircraft design process. However, a consistent void in aircraft design is the ability to integrate high-fidelity computational capabilities from multiple disciplines within an organized MDO environment. Integrating high fidelity simulation technology (that has been developed over the years though significant investments) within a MDO environment will constitute a disruptive technological development in aircraft design. The ability to replace time consuming solvers with metamodels within the highly iterative environment of an integrated network of optimizations is critical for engaging high fidelity simulation tools in the MDO analysis of complex aircraft systems. Previous work completed by the proposing firm has demonstrated the feasibility of conducting such MDO analysis for an aircraft system, while considering outer mold line shape optimization and structural sizing simultaneously. Since the ability to create metamodels from results obtained at a number of sample points from the actual solvers is the key enabling factor for conducting the multi-discipline optimization analysis, the proposed project will use as foundation the existing metamodeling capability of the proposing firm and will pursue new research that will lead to the development of a powerful stand-alone commercial product for metamodel development. The latter, along with the proposing firm's MDO solver will provide the means for operating an integrated network of optimizations for designing aircraft systems.

SBIR	09	1	X8.01-8314	NNX10CE60P	Micro Cooling Concepts, Inc.	Microplate Heat Exchanger	$99,358.00	We propose a microplate heat exchanger for cryogenic cooling systems used for continuous flow distributed cooling systems, large focal plane arrays, multiple cooling locations, and very low vibration cooling systems. Any DC cryogenic flow system such as turbo Brayton, Joule-Thomson (JT), or remote cooling applications require very high effectiveness heat exchangers to reduce input power. The parasitic loads from heat exchangers are a significant fraction of the overall load, and high effectiveness heat exchangers lead directly to improved system efficiencies across a broad range of cryogenic applications. Microplate heat exchangers have a demonstrated effectiveness over 98% (Marquardt, Cryocoolers 15). While performance is high, they will be difficult to use for larger cryogenic flow systems due to parasitic conduction losses inherent in the materials available for the **manufacturing** process. A material change will allow more compact heat exchangers with lower parasitic losses. Other limitations of the **manufacturing** process make yields low, and while it may be possible to push the effectiveness higher, it may be difficult to consistently produce high performing exchangers using the current approach. We propose a new bi-metal microplate heat exchanger which is unique in that it uses the **manufacturing** process to control critical heat exchanger dimensions that are inherently similar across all parts, allowing high effectiveness without the need for close inspection of every part and the low yield which results from hand inspection. We further include additional features within the flow channels that automatically balance the mass flows within the heat exchanger to push the effectiveness even higher. This is accomplished in the most compact cryogenic heat exchangers theoretically possible to build using parallel plate flow channels.
SBIR	09	1	S3.03-8143	NNX10CD01P	MicroLink Devices	High Radiation Resistance Inverted Metamorphic Solar Cell	$100,000.00	The innovation in the proposed SBIR Phase I project is the development of a unique triple unction inverted metamorphic technology (IMM), which will enable the **manufacture** of very lightweight, low-cost InP-based multijunction solar cells. The proposed IMM technology will consist of an all indium and phosphorous-based structure, which is designed to improve the radiation resistance properties of the triple junction solar cell. Because of the intrinsic radiation hardness of InP materials, this material system is of great interest for building solar cells suitable for deployment in very demanding radiation environments such as medium earth orbit and missions to the outer planets. It is expected that an efficiency greater than 30% could be realized with this new IMM structure.

SBIR	09	1	X2.02-9318	NNX10RA53P	Nanoscale Materi	Odor Control in Spacecraft Waste Management	$100,000.00	Spacecraft and lunar bases generate a variety of wastes containing water, including food wastes, feces, and brines. Disposal of these wastes, as well as recovery of water, is necessary. However, evaporation of water also evaporates compounds with foul odors, some of which are much more volatile than water. Even apart from a water recovery system, foul odors sap crew morale, and must be eliminated. NanoScale^{REG} Corporation has developed a formulation of its proprietary sorbents, termed OdorKlenz^{TM}, that has been shown to effectively remove odorous compounds from air by destructive adsorption. NanoScale proposes development of a similar formulation, built around nanocrystalline metal oxides **manufactured** by NanoScale

SBIR	09	1	X5.02-8504	NNX10CF11P	Nanotrons	Functionalized Graphene Sheets-Polymer Based Nanocomposite for Cryotanks	$99,944.00	NASA seeks advanced high strength and toughness composite materials with the highest microcrack resistance at cryogenic temperatures suitable for use in fuel containment of liquid oxygen, hydrogen, and methane. Nanotrons Corporation, in collaboration with Prof. Bungki Kim at NSF **nanomanufacturing** research center in Univer
SBIR	09	1	X7.01-8216	NNX10CD30P	NEI Corporation	High Energy Density Li-ion Batteries Designed for Low Temperature Applications	$99,999.00	NEI Corporation proposes to develop a mixed metal oxide nanocomposite cathode that is designed for delivering high energy density with good rate performance at low temperatures (T=0 C). The two-fold innovation in the proposed effort is the simultaneous intrinsic (i.e. defect chemistry) and extrinsic (electrically conductive surface coating) modification to the active material, which itself is a composite of two layered materials. The proposed intrinsic and extrinsic modifications are projected to beneficially impact both ionic and electronic conductivities of the cathode material, and thereby enhance the Li-ion cell performance at low operating temperatures. The target specific capacity of the proposed cathode is more than 300 mAh/g with a nominal working voltage of 3V, and delivering more than 900 Wh/kg specific energy at T=0 C. The objective of the Phase I program is to demonstrate the feasibility of a new high capacity and high voltage cathode material for rechargeable Li-ion batteries. In Phase II, the composition and morphology of the powders will be optimized, and integrated into large format prototype Li-ion batteries by working in partnership with a battery **manufacturer**(s).

SBIR	09	1	S1.08-8096	NNX10CF12P	Novawave Technd	Fieldable, Real-Time NO2 Sensor	$100,000.00	This Small Business Innovative Research Phase I proposal seeks to develop a compact, autonomous NO2 sensor for air monitoring applications based on laser induced fluorescence (LIF). A key component in the proposed system is new laser technology developed at NovaWave. The Phase I research will directly demonstrate the utility of this new light source by performing LIF measurements on NO2 samples in a laboratory setting. The Phase II system will fully integrate the laser with an autonomous spectrometer and air sampling system to comprise a complete sensor package. Phase III will result in the development of fieldable commercial systems that will be **manufactured** and distributed to the regional end users.
SBIR	09	1	S1.02-8927	NNX10RA60P	Nuvotronics, LLC	3D High Density mmWave Interconnects	$99,976.00	Nuvotronics has developed and optimized the PolyStrata^{TM} process for the fabrication of intricate microwave and millimeter-wave devices. These devices have primarily been rectangular coaxial transmission lines, although rectangular waveguide and other structures have also been demonstrated. Intricate devices have been demonstrated with insertion loss 5 to 10 times lower than traditional planar circuits; isolation better than 60dB for lines that share separating walls; multiple levels of densely-packed coaxial circuits; and low-parasitic attachment to active devices and traditional circuit boards. In this Phase I project, Nuvotronics is proposing to develop high density low-loss millimeter backplane circuits to package and interconnect components of future NASA millimeter wave (MMW) radars. The significance of the innovation primarily lies in three areas: reduction of system size, weight and loss in MMW radars. The PolyStrata technology is a batch **manufacturing** process, providing economies of scale and cost reduction for higher volumes, in addition to flexibility in design for various frequencies of interest. Nuvotronics will design and test select Polystrata interconnects at MMW frequencies of interest, with particular attention to performance over temperature and survivability to launch conditions. The result of the Phase I research will prove the feasibilty of utlizing the Polystrata MMW backplane technology in future NASA missions, and provide the foundation for full scale development, testing, and prototype delivery during the Phase II project.

SBIR	09	1	X4.02-9770	NNX10CF10P	Paragon Space Development Corporation	Verification and Validation of an Innovative Inflatable Structure Design	$99,987.00	An inflatable habitat is a pressure vessel with flexible shell. Notable features such as low weight, large inflated operational volume, and small pre-deployment volume offer significant advantages over traditional rigid metallic and composite habitat structures. Conventional designs suffer from indeterminacy of load sharing between meridional and circumferential members as well as the internally rigid metal support structure. The designs must functionally index the meridional and circumferential members to one another to minimize sensitivity to **manufacturing**, handling and operational trauma, all the while maintaining their independent load carrying roles. This design process results in oversized members to account for load uncertainties. The unique Ultra High Performance Vessel (UHPV) technology provides the solution to the design and **manufacture** of robust inflatable

SBIR	09	1	X6.02-8920	NNX10CF35P	Plasma Processes	Mass Production of Mature Lunar Regolith Simulant	$100,000.00	As NASA prepares for future exploration activities on the Moon, there is a growing need to develop higher fidelity lunar soil simulants that can accurately reproduce the properties and behavior of lunar soil. Simulants are employed on earth to verify the performance of equipment, mechanisms, structures and processes to be used on the lunar surface. One of the significant limitations of current simulants is the lack of constituents, such as agglutinates and spherules, which often contain nano-phase iron (Fe0). These constituents are needed in any high fidelity simulant. Recently, Plasma Processes, Inc. (PPI) has developed a process to create simulated agglutinates and volcanic glasses from JSC-1A lunar regolith simulant. Microstructural characterization has shown that these components contain an appreciable amount of nano phase Fe0. However, current production of these simulant additives is limited. The ultimate objective of this Phase I effort is to develop an economical, large scale **manufacturing** process to produce simulant agglutinates and volcanic glasses. This production process promises to be a viable route for significantly enhancing the fidelity of existing and future lunar regolith simulants.
SBIR	09	1	X1.03-9811	NNX10CF02P	SJT Micropower	Unconditionally Stable Low Dropout Regulators for Extreme Environments	$99,949.00	We have developed a fully integrated LDO regulator using a patented transistor technology that can be **manufactured** in high volume commercial semiconductor foundries with no changes to the process flow. The regulator is stable under all load conditions without the need for an external compensation capacitor thereby reducing the mass/volume of the power management system and increasing reliability. The existing LDO component has very competitive figures of merit (dropout voltage, transient response, power supply rejection) compared to existing components targeting commercial consumer electronics. The work we are proposing for this Phase 1 activity will confirm the expected wide temperature range operation (-180C to +150C) and radiation tolerance (200krads(Si) to 1 Mrad(Si)) of the existing component. Based on these measurements we shall design, simulate and layout LDO regulators for nominal load currents of 100 mA and 1A for fabrication at two rad-hard CMOS foundries during a follow-on Phase 2 activity. The LDO regulators will be designed as drop-in replacements for many existing components. They can also be integrated directly on chip as part of an application specific integrated circuit thereby reducing the chip count still further.

SBIR	09	1	A2.02-8182	NNX10CC73P	Sun Valley Techn	Multi-Element Lean Direct Injection Combustor Single Element Demonstration	$99,378.00	We propose to demonstrate the feasibility in a single element of a Multi-Element Lean Direct Injection, ME-LDI, Combustion concept. The concept will have the following innovative features: 1. Independent, mini burning zones created by containing the flame in a cylinder downstream of each fuel injector/swirler element in a multiple fuel injector array, see figure 1. The independent burning zones will enable fuel staging the fuel injectors (turning off fuel to selected fuel injectors) to cover the operating cycle, such that at each point of the operating cycle the combustor will have high combustion efficiency (>99%) and low NOx emissions. At high power conditions the combustion efficiency should be greater than 99.9%. 2. A plain-jet hypodermic fuel injector fuel injector will be incorporated into ME-LDI that is low cost and simple to **manufacture** but a highly effective atomizer. Modified plain-jet fuel injectors will be studied including an injector with a tip that has a diverging nozzle and one that has a spin chamber at the exit. These alternative plain-jet fuel injectors will increase the surface area at the exit of the injector resulting in a thinner film for better atomization and fuel-air mixing. 3. A restrictor plate upstream of each fuel injector to provide a steady flow to each fuel injector and prevent any feedback from an unsteady flame to the fuel supply
SBIR	09	1	S1.07-8699	NNX10CD63P	Superconducting Systems, Inc.	Application of Reinforced HTS 2212 Wires in ADR Magnets Operating at 30K-40K	$99,844.00	Adiabatic Demagnetization Refrigerators (ADRs) are considered for operations in many space missions. At the heart of an ADR is a magnet that produces the background field necessary for demagnetization of a paramagnetic material. To achieve very low temperatures, all sources of heat need to be eliminated or minimized, making superconducting magnets an obvious choice. The size and power requirement of current cryocoolers that cool such superconducting magnets to about 4K make them unrealistic for space missions. ADR magnets that can operate at 30K-40K require simpler cooling systems and are more suited to space applications. This requires the coils to be fabricated from HTS wires. Phase I of this work aims to **manufacture** 0.2mm diameter Bi2212/Ag wires and fabricate a 1T 30mm dia. x 62mm long superconducting coil that can operate at 30-40K. Since 2002 our company has been the beneficiary of SBIR awards in the area of developing light-weight low-current ADR magnets operating at 10K by using Nb3Sn superconducting wires in **manufacturing** of ADR magnets, and successfully fabricated demonstration magnets that were provided to NASA Goddard Space Flight Center. All the developed techniques, procedures and the equipment will directly be applied to the aims of this proposal.

SBIR	09	1	X14.01-9315	NNX10CC45P	Synkera Technolo	Nanorod Array Solid State Neutron Detectors	$99,897.00	In this Phase I SBIR project, Synkera proposes to develop and commercialize solid-state neutron detectors of a unique architecture that will enable sensor modules for a variety of operating environment. The neutron detectors are based around nanoporous anodic aluminum oxide, and will be fabricated using a combination of gas-phase and solution-based deposition methods. The detectors will incorporate a schottky junction surrounding a neutron-conversion material. As part of this development effort we will develop the deposition methods required for the various components of the detector and use modeling to evaluate the feasibility of the design. Our solid-state neutron detectors are expected to have much larger neutron sensitivity toward fast neutrons than conventional detectors at a lower weight and much lower power requirements. These features will enable solid state neutron spectrometers meeting all the NASA requirements on weight, volume, and power. We anticipate that large detector areas can be **manufactured** at costs below those of conventional neutron detectors.
SBIR	09	1	O1.07-9857	NNX10CD94P	The IIIAN Compa	GaN Bulk Growth and Epitaxy from Ca-Ga-N Solutions	$99,582.00	This SBIR proposal addresses the liquid phase epitaxy (LPE) of gallium nitride (GaN) films using nitrogen-enriched metal solutions. Growth of GaN from solutions offers the possibility of drastically reducing the density of line defects. As these defects adversely affect both breakdown voltages and electron velocities, their reduction can significantly increase the performance of high power Ka-band HEMT structures used for satellite communications. To achieve low defect densities in GaN films and efficient, large scale **manufacturing**, IIIAN will utilize new chemical growth methods based on nitrogen-enriched metal solutions, in particular the Ca-Ga-N ternary system. In the binary calcium-gallium alloy system it is possible to achieve a nitrogen atomic fraction of 2% at 900 oC and 2 bar. This is a significantly higher fraction than is possible in pure gallium solutions. For example, a temperature of ~1700 oC and pressure of ~10 kbar are necessary to achieve even 0.1% atomic nitrogen fraction in pure gallium solvent.

SBIR	09	1	A2.01-8248	NNX10CC67P	Transition45 Technologies, Inc.	Shape Memory Alloy-Based Periodic Cellular Structures	$100,000.00	This SBIR Phase I effort will develop and demonstrate an innovative shape memory alloy (SMA) periodic cellular structural technology. Periodic cellular structures (PCS) will be designed and tailored to determine if additional shape memory performance benefits can be derived from the underlying macro-structure when fabricated from SMA's. These structures will be **manufactured** using an advanced reactive metal casting technology that will allow complex-shaped, integral bulk structures to be fabricated with the requisite composition-microstructure-properties needed for shape memory performance. Casting also offers a relatively low-cost approach for fabricating near net-shape components. The fabricated SMA structures will be characterized for resulting microstructure-properties in order to determine how to best design such PCS to better exploit SMA's for use in aerospace applications.
SBIR	09	1	A2.01-9895	NNX10CC72P	Ultracor	C-SiC Honeycomb for Advanced Flight Structures	$93,662.00	The proposed project is to **manufacture** a C-SiC honeycomb structure to use as a high temperature material in advanced aircraft, spacecraft and industrial applications. The proposers will fabricate a carbon fiber honeycomb structure. The structure will be charred and then converted to C-SiC by means of chemical vapor infiltration. The resultant material will then be tested mechanically at ambient, at high temperature and then at ambient after high temperature exposure.

SBIR	09	1	X8.01-8628	NNX10CE62P	Ultramet	Aerogel-Filled Foam Core Insulation for Cryogenic Propellant Storage	$100,000.00	Current cryogenic insulation materials suffer from various drawbacks including high cost and weight, lack of structural or load-bearing capability, fabrication complexity, and property anisotropy. A need clearly exists for lightweight thermal insulation that is isotropic, structurally capable, and exhibits improved thermal performance relative to current materials and structures. Aerogels have been investigated as an insulation material for cryogenic tanks due to their ultralow thermal conductivity and density, but they suffer from poor structural integrity and require expensive processing. Open-cell foam structures have also been researched, but suffer from the requirement for high vacuum in order to perform adequately. In previous work for NASA and DoD involving lightweight structural insulation for high temperature engine and airframe applications, Ultramet developed and demonstrated lightweight open-cell foam insulators composed of a carbon or ceramic structural foam skeleton filled with a low-cost, nanoscale aerogel insulator. The potential exists to adapt and optimize aerogel-filled structural foam for the cryogenic insulation application, thereby taking advantage of the thermal and mechanical benefits of each component while also offering low cost and **manufacturability** in complex shapes. In this project, Ultramet will team with Alliant Techsystems (ATK), a leading aerospace firm, to demonstrate the initial feasibility of the innovative cryogenic insulation to meet NASA requirements.

SBIR	09	1	X5.03-9347	NNX10CF31P	Wright Materials Research Co.	Manufacturing of Nanocomposite Carbon Fibers and Composite Cylinders	$100,000.00	Lightweight structures has enormous potential for space vehicles applications as the reduction of weight from metallic structures add to vehicle performance, reduce launching and maintenance costs. The high strength, superior stiffness, and lightweight characteristics of carbon fibers have created enormous interest as reinforcing element for use in various structures of polymer matrix composites. Majority of the commercial carbon fibers are produced from a PAN and pitch precursors. Since carbon fiber is the key constituent material in composite materials that contribute to the load carrying capability of composite structures any improvements in carbon fiber properties and **manufacturing** process is vital for the further improvement and application of composite structures. In this SBIR Phase I project we propose to develop pitch-based nanocomposite carbon fibers and use them for **manufacturing** of composite cylinders via a filament winding technique. These nanocomposite carbon fibers and the associated composite structures will possess excellent structural, thermal and electrical conductivity properties. Preliminary research results indicated that the proposed idea is very promising. The results of the proposed research will contribute to NASA's goal of performance enhancement, and reduction of launching and maintenance costs.
SBIR	09	1	S2.05-9304	NNX10CD72P	Zeeko Technologi	In Situ Metrology for the Corrective Polishing of Replicating Mandrels	$99,314.00	The International X-Ray observatory (IXO) is due to be launched in 2021. The core of the instrument is a very large (3.2 meter diameter) Wolter I optic, to be assembled from approximately 13,000 individual elements. Each element will, in turn, be created by 'slumping' glass over a precision mandrel, of which there must be in excess of 700. In addition to the very large size of the mandrels (up to 1.6 meter radius), figure and size tolerances are exceedingly tight, ranging from 2 nanometers (axial figure) to 200 nanometers (radius variation). The combination of size, accuracies, production rate requirements and the number of individual component designs defy standard optical metrology techniques. While polishing equipment that can meet these tolerances exists, the polishers must be controlled by continuous or near continuous (process intermittent) feedback. In this effort we propose to develop a unique "point-defined" metrology instrument that can be incorporated into the polishing machine itself, to control the **manufacturing** process to the required levels of accuracy. In Phase 1 we will develop conceptual designs for both stand-alone and on-machine instrumentation. In Phase 2 we will develop a stand-alone metrology instrument, and in Phase 3 we will fully incorporate the technology onto a commercial polishing instrument.

SBIR	09	1	A2.08-9796	NNX10CC80P	ZONA Technology	Multi-Fidelity Multi-Strategy and Multi-Disciplinary Design Optimization Environment	$99,873.00	Multidisciplinary design and optimization (MDO) tools developed to perform multi-disciplinary analysis based on low fidelity computation methods have been used in aircraft conceptual design for decades. These tools have been proven very effective for simple problems and mostly have been developed as a single codes. However, as analyses have become more complex and the need to consider more design factors crucial, such codes have grown so large as to be inconceivable and difficult to maintain. Nowadays, the design optimization process of a modern airplane must account for all failure modes and behavior constraints. In addition, it should cover **manufacturing** constraints and limitations on available resources, such as power, weight, and cost, simultaneously. This has to be done in an integrated way, so that the effects of any change in the design on all constraints and behavior measures are accurately modeled, and all interactions and trade-offs among design variables and disciplines are allowed to affect the design. ZONA Technology (ZONA) and its team member (Virginia Polytechnic Institute and State University), hereinafter referred to as "the ZONA team", propose in Phase I to develop a multi-fidelity, multi-strategy and multi-disciplinary design optimization environment, called the M3 Design Optimization Environment (M3 DOE) that consists of a three-layer optimization strategy, a multi-fidelity aerodynamic discipline, and a finite element analysis including outer mold line morphing and topology re-meshing capability. The M3 DOE allows the designer to select an appropriate optimization strategy and an aerodynamic method with an appropriate fidelity to obtain an optimum design with desired accuracy within the allowable time constraint.

SBIR	09	1	X6.02-8148	NNX10CF34P	Zybek Advanced Products, Inc.	High Fidelity, High Volume Agglutinate Manufacturing Process	$98,700.00	Up to 65% of the lunar soils are comprised of agglutinates. Although the importance of agglutinate in simulants is often debated, the fact is that agglutinates account for a large portion of the lunar soil and have known effects on final material properties. Increasing the fidelity of terrestrially **manufactured** simulant can reduce mission risk. Zybek Advanced Products, Inc., is proposing an important innovation to the agglutinate **manufacturing** process to address mission-critical needs for lunar regolith simulants that achieve NASA's cost and quantity objectives, provide reproducible production processes, and supply required particle size distributions. Additional value is provided to the program by ZAP's unique knowledge of simulant mechanical and material properties gleaned from its production of simulant components for NASA. The majority of ZAP's work completed to date has been focused on high volume, bulk lunar simulant components, including glass, agglutinates and melt breccias. The primary purpose of this SBIR proposal is to innovate the agglutinate **manufacturing** process to provide significantly higher quality material that will contain nanostructure Fe0. This innovation will leverage ZAP's current investment in the high-volume simulant **manufacturing** and provide the industry with more accurate simulants that will reduce future mission risks.

Program	Program Year	Phase	Proposal#	Contract#	Firm Name	Proposal Title	Award Amount	Proposal Abstract
STTR	09	1	T1.02-9908	NNX10RA82P	Balcones Technologies, LLC	Active Electromechanical Suspension System for Planetary Rovers	$99,992.00	Balcones Technologies, LLC proposes to adapt actively controlled suspension technology developed by The University of Texas at Austin Center for Electromechanics (CEM) for high performance off-road vehicles to address STTR 2009-1 Subtopic T1.02, Information Technologies for Intelligent Planetary Robots. In particular, our team will develop a concept design for an actively controlled ElectroMechanical Suspension (EMS) system, including algorithms, software and hardware, that dramatically improves mobility for MER to MSL scale rovers. Our system exploits and adapts approximately $25M of highly successful active suspension R&D at CEM since 1993. It also exploits CEM's experience developing electromechanical systems for space applications gained during NASA funded programs to develop flywheel energy storage system technology for the International Space Station. Finally, it exploits our team's extensive experience migrating University technology to commercially viable **manufacturable** products. Relevant features of our anticipated solution include: Â Capable of vehicle speeds exceeding 3 m/s over lunar relevant terrain while maintaining hyper-stability for payloads of 100 kg or more Â Large suspension travel to enable obstacle negotiation Â Control system that can operate autonomously or slaved to higher level vehicle controller for specialized operations such as obstacle negotiation Â Four quadrant actuator control, capable of power regeneration for damping operations to improve system efficiency Â Passive springs to support rover static weight (no power consumption to support static weight) Â Highly efficient electromechanical

STTR	09	1	T3.01-9864	NNX10CF58P	CFX Battery, Inc.	Biotemplated Nano-Structured Materials for Advanced Li-ion Batteries	$100,000.00	NASA has identified a critical need for pioneering advances in battery technology to give high performance, low-weight, durable and long-life power sources for future missions. In this Phase I proposal, CFX Battery, Inc. and Georgia Institute of Technology propose the chemical conversion of micron-sized, nano-structured templates available from renewable resources into functional electrode materials. In nature, diatom species form complex cell wall structures made of silica through biological self-assembly. We will take advantage of these intricate structures to generate hierarchically-ordered functional nanocrystalline oxide architectures, and investigate the application of these materials in electrochemical devices. We intend to establish that electrodes fabricated from these nanostructures are innovative materials that display improved electrochemical performance compared to traditional electrodes. This will enable us to address the significant increases in energy capacity, power capability and cycling stability necessary to meet the NASA requirements for advanced Li-ion battery technology. Our **manufacturing** strategy is conceptually-straightforward, rapid, scalable and amenable to commercialization.
STTR	09	1	T3.01-9972	NNX10CF61P	Firefly Technologies	Nanowire Photovoltaic Devices	$99,887.00	Firefly, in collaboration with Rochester Institute of Technology, proposes an STTR program for the development of a space solar cell having record efficiency exceeding 40% (AM0) by the introduction of nanowires within the active region of the current limiting sub-cell. The introduction of these nanoscale features will enable realization of an intermediate band solar cell (IBSC), while simultaneously increasing the effective absorption volume that can otherwise limit short circuit current generated by thin quantized layers. The triple junction cell follows conventional designs comprised of bottom Ge cell (0.67eV), a current-limiting middle GaAs (1.43eV) cell, and a top InGaP (1.90eV) cell. The GaAs cell will be modified to contain InAs nanowires to enable an IBSC, which is predicted to demonstrate ~45% efficiency under 1-sun AM0 conditions. The InAs nanowires will be implemented in-situ within the epitaxy environment which is a significant innovation relative to conventional semiconductor nanowire generation using ex-situ gold nanoparticles. Successful completion of the proposed work will result in ultra-high efficiency, radiation-tolerant space solar cells that are compatible with existing **manufacturing** processes. Significant cost savings are expected with higher efficiency cells which enables increased payload capability and longer mission durations.

STTR	09	1	T6.01-9917	NNX10RA90P	Nanoscale Materials, Inc.	Metal Oxide-Carbon Nanocomposites for Aqueous and Nonaqueous Supercapacitors	$100,000.00	This Small Business Innovation Research Phase I effort focuses on development of novel metal-oxide-carbon nanocomposites for application in pseudocapacitive electrochemical supercapacitors. Specifically, nanocomposites based on manganese, titanium, tantalum and vanadium oxides will be incorporated, at the nanoscale level, with electrically conductive carbon supports. Our focus will be to combine the desired pseudocapacitive characteristics of metal oxides with high surface area and large electrical conductivity of carbon supports while achieving economical and scalable **manufacturing**. The proposed nanocomposite materials will be tested as electrode materials in aqueous and nonaqueous supercapacitors. The proposed project will be a joint effort on NanoScale Corporation and Battelle Memorial Institute. NanoScale's role in the effort will be to synthesize nanocomposite materials, characterize their physical and chemical properties, and to optimize them based on results of electrochemical testing carried out by Battelle. Battelle's role in the effort will be to take the metal oxides prepared by NanoScale and fabricate them into supercapacitor elements to be tested in half-cell and full-cell devices. NanoScale is uniquely qualified to carry out the proposed research due to its rich experience in development and scaled-up synthesis of nanosized materials, including materials for battery applications. NanoScale has worked previously on several projects related to battery technologies.

STTR	09	1	T3.01-9920	NNX10RA85P	Nanosonic, Inc.	Radiation Resistant, Reconfigurable, Shape Memory Metal Rubber Space Arrays	$100,000.00	NanoSonic has demonstrated that Shape Memory Metal Rubber^{TM} (SM-MR) adaptive skins exhibit reconfigurable and durable RF properties. It is hypothesized that such morphing skins shall also exhibit durable radiation resistance upon morphing; a property that few, if any, flexible materials offer. Typical highly filled or metal evaporated nanocomposites crack and spall upon flexation, and cannot be repeatedly mechanically stretched without rupture after a few cyclic strains. SM-MR nanostructured morphing materials are based on self-assembled high z, dense, Au and Ag nanoparticles, rather than Pb. Our **manufacturing** process yields tough skins that can be repeatedly and severely mechanically morphed without loss of EMI shielding (-88dB). NanoSonic, together with Colorado State University, have demonstrated that SM-MR is up to 50% lighter in weight and provides greater gamma ray attenuation relative to commercial off-the-shelf shielding materials, without emitting harmful secondary radiation under a 137Cs source. During Phase I, radiation shielding would be verified for SM-MR during potential disparate space array morphed configurations to demonstrate durability, stowability, and reconfigurability for space tolerant structures with self-healing properties to reach TRL6. TRL8 and 9 shall be reached during Phase II and III with assistance from our space systems prime partner upon flight testing and integration.

STTR	09	1	T6.01-9894	NNX10CF68P	Nanosonic, Inc.	Self Assembled Carbon Nanotube Enhanced Ultracapacitors	$100,000.00	The objective of this NASA STTR program is to develop single wall carbon nanotube (SWCNT) based ultracapacitors for energy storage devices (ESD) application, using NanoSonic's patented molecular level self-assembly process performed at room temperature. Specifically, we would combine advances in metallic SWCNTs, metal and oxide nanoclusters, and polymeric materials and electrostatic self-assembly (ESA) processes, to enable large-area, low-cost and integrated device **manufacturing** on rigid and flexible substrates. Such a combination of solution-based thin film deposition approaches to form ultracapacitor based devices and materials offers advantages over conventional high temperature and costly processes such as vacuum processes and vapour-phase deposition, in that very different materials can be incorporated uniformly at room temperature and pressure. We will perform synthesis of SWCNT and other precursors that can be used for ESA processing and transitioned to deposition of two-dimensional patterned materials. Layer by Layer fabrication of multilayered CNT enhanced ultracapacitors leads to the analysis of chemical, physical and optical properties during and after synthesis, and verification of material morphology and response. We will study the cyclic voltammetric (CV) behavior and derive the power density from the inner integrated area. We will also investigate the specific capacitance as a function of discharge current density. From here, NanoSonic and Virginia Tech will develop an equivalent circuit model of the CNT ultracapacitor device for NASA applications. NanoSonic and Virginia Tech will also experimentally validate CNT ultracapacitor

STTR	09	1	T3.01-9921	NNX10RA86P	Plasma Processes, LLC.	Microchannel Thermo Catalytic Ignition for Advanced Mono- and Bipropellants	$100,000.00	Small and micro-spacecrafts require the efficient, micro-propulsion systems. Chemical micro-propulsion is best suited for use as primary thrust, orbital insertion and attitude control because of its high energy density. When grouped into arrays for larger thrust applications, micro-propulsion devices provide high propulsive flexibility or can be used as igniters. The proposed effort will focus on thermo-catalytic ignition and combustion of advanced mono- and bi-propellants in micro-channels; and the development of a micro-propulsion device. An innovative near net shape forming technique, in combination with carbon nanotube deposition, will facilitate **manufacturing** of sub-millimeter diameter micro-channels and tubes with enhanced internal surfaces area for maximum catalytic reaction. The microchannels will provide thermo-catalytic ignition of bi-propellant rockets without needing high voltage igniters and can also provide stable and reliable ignition source for advanced, environmentally friendly, mono-propellants.
STTR	09	1	T2.01-9961	NNX10CF56P	Stirling Dynamics, Inc.	Aeroelastic/Aeroservoelastic Uncertainty and Reliability of Advanced Aerospace Vehicles in Flight and Ground Operations	$100,000.00	ASSURE - Aeroelastic / Aeroservoelastic (AE/ASE) Uncertainty and Reliability Engineering capability - is a set of probabilistic computer programs for isolating uncertainties in simulation, **manufacturing**, test, measurement, and test to analysis correlation affecting the AE/ASE characteristics of advanced flight vehicles in flight and on the ground, and for studying the effects of such uncertainties. ASSURE will provide a quantitative assessment of the statistics of AE/ASE stability and dynamic response of aircraft at given flight conditions, throughout the flight envelope, on the runway, and throughout the aircraft fleet and its missions. It is designed to have significant flexibility in the types of problems analyzed, the solution methods used, and how problems are defined. ASSURE will be unique in the scope of problems tackled, systems complexity involved, and the inclusion of all elements affecting the ASE behavior of flight vehicles; including detailed models of structures, aerodynamics, sensors, actuators, control systems, landing gear, and flight operations and maintenance procedures. Uncertainties of the undamaged and damaged / repaired systems (structural, actuator, sensor, control computer, and landing gear, including possible aerodynamic consequences of damage) will be covered, with applications to test planning and analysis, design, certification, and fleet operation and maintenance.

Program	Program Year	Phase	Proposal#	Contract#	Firm Name	Proposal Title	Award Amount	Proposal Abstract
SBIR	08	2	X2.03-9021	NNX10CA22C	Advanced Fuel Research, Inc.	A Compact, Efficient Pyrolysis/Oxidation System for Solid Waste Resource Recovery in Space	$599,858.00	Pyrolysis processing can be used in near term missions for volume reduction, water recovery (drying), stabilization, and enhanced water and oxygen recovery through thermochemical reactions. For longer term missions, the added benefits include production of fuel, multi-purpose carbon, and reactants for in-situ resource utilization (ISRU). The objective of the Phase I SBIR program was to demonstrate the feasibility of integrating pyrolysis, tar cracking, and oxidation steps into a compact, efficient, system for processing spacecraft solid wastes. This integration, which was based on a microwave pyrolysis/cracking/oxidation unit, has resulted in a significant reduction in energy consumption per gram (~70% when compared to a conventional unit), and an overall reduction in system complexity. These improvements should lead to a lower Equivalent System Mass (ESM) for a full scale system. Under Phase II, a prototype microwave pyrolysis/tar cracking/oxidation unit will be developed in collaboration with ETM Electromatic, Inc., a leading **manufacturer** of microwave power systems for commercial, space and military markets.
SBIR	08	2	O1.06-9563	NNX10CA72C	aPeak, Inc.	High-Bandwidth Photon-Counting Detectors with Enhanced Near-Infrared Response	$599,513.00	Long-range optical telecommunications (LROT) impose challenging requirements on detector array sensitivity at 1064nm and arrays timing bandwidth. Large photonic arrays with integrated beam acquisition, tracking and/or communication capabilities, and smart pixel architecture should allow the implementation of more reliable and robust LROT systems. Integration of smart pixel technology for parallel data acquisition and processing is currently available in silicon. Current silicon photon-counting detector arrays benefit from a worldwide **manufacturing** and R&D infrastructure but their response at 1064nm is not suitable for LROT. In Phase I we proposed to verify the feasibility of increasing the responsivity of aPeak's silicon photon counting arrays at 1064nm by increasing their quantum absorption efficiency and demonstrating sub-nanosecond timing resolution. Phase I resulted in photon counting arrays with enhanced response at 1064 nm. Modules to be implemented into the readout IC (ROIC) have been fabricated in compact ASIC designs, suitable for integration into the smart pixel fabric [A] they have demonstrated 100ps timing jitter and have exceeded the dynamic range requirements. Noise, timing resolution, and linearity requirements meet updated program requirements Phase II program builds upon Phase I results and previous smart pixel development at aPeak Inc with the aim to develop photon-counting arrays with enhanced 1064nm response and integrated counters at pixel level, capable of high - timing resolution and high counting rate. We propose to develop the photon counting detector arrays, associated ROIC arrays in ASIC, technology to assemble the detector and ROIC arrays, as well as in process ASIC mapping and maskless correction methods critical for the detector fabrication. Detector array design will be improved to meet the detection efficiency at 1064nm, while preserving or improving the detector noise, timing resolution, and linearity demonstrated in Phase I

SBIR	08	2	X1.02-8609	NNX10CA19C	Aries Design Automation, LLC	An Efficient Parallel SAT Solver Exploiting Multi-Core Environments	$600,000.00	The hundreds of stream cores in the latest graphics processors (GPUs), and the possibility to execute non-graphics computations on them, open unprecedented levels of parallelism at a very low cost. In the last 6 years, GPUs had an increasing performance advantage of an order of magnitude relative to x86 CPUs. Furthermore, this performance advantage will continue to increase in the next 20 years because of the scalability of the chip **manufacturing** processes. The goal of this project is to efficiently exploit the GPU parallelism in order to accelerate the execution of a Boolean Satisfiability (SAT) solver. SAT has a wide range of applications, including formal verification and testing of software and hardware, scheduling and planning, cryptanalysis, and detection of security vulnerabilities and malicious intent in software. We bring a tremendous expertise in SAT solving, formal verification, and solving of Constraint Satisfaction Problems (CSPs) by efficient translation to SAT. In our previous work (done on the expenses of our company) we achieved 2 orders of magnitude speedup in solving Boolean formulas from formal verification of complex pipelined microprocessors, 4 orders of magnitude speedup in SAT-based solving of CSPs, and 8 orders of magnitude speedup in SAT-based routing of optical networks. During Phase 1 we implemented a prototype of a parallel GPU-based SAT solver that is 1 2 orders of magnitude faster than the best sequential SAT solvers. In Phase 2, we will continue to exploit the GPU parallelism to accelerate SAT solving, and expect to achieve speedup of 3 4 orders of magnitude.
SBIR	08	2	S2.04-9926	NNX10CB49C	Dallas Optical Systems, Inc.	Low Cost Very Large Diamond Turned Metal Mirror	$596,534.00	Electrolytic plating of high phosphorus nickel phosphorus alloy will encapsulate a machined mirror substrate master made of fine cell plastic foam such as polystyrene that has been sealed and made electrically conductive with painted-on coatings. After encapsulation with up to one millimeter of NiP metal holes will be drilled and the plastic master will be dissolved with a solvent such as acetone and removed. Prior to encapsulation plating round or other cross section tubes are inserted thru holes in the plastic foam so that they are incorporated into the electroformed mirror structure when the master is encapsulated with more NiP. The tubes which connect the front and back surfaces of the mirror are made by electroforming with the same NiP alloy. The finished mirror substrate will be diamond turned and the very low cutting force diamond turning process will allow fabrication of a very thin mirror face plate without print through since there is only a very low pressure on the mirror from diamond turning. Machining of plastic foam is accomplished very quickly and the foam material is very low cost. In a production mode the expendable foam plastic masters could themselves be molded. The size of the mirrors is only limited by the capacities of the plating bath and the diamond turning machine. The process is applicable to any optical contour and to the **manufacture** of off-axis segments.

SBIR	08	2	X12.02-9041	NNX10CB04C	EIC Laboratories, Inc.	Flexible High-Barrier Polymers for Food Packaging	$599,999.00	The development of a polymer laminate with water and oxygen barrier properties suitable for food packaging and preservation on 3-5 year manned space exploration missions is proposed. The laminate is a multilayer structure comprising polymer and inorganic dielectrics that will provide near-hermetic encapsulation of food items for the duration of these missions. In Phase I, flexible polymer barriers with an oxygen transport rate of <0.005 cc/m2-day and water transport rate of <0.005 g/m2-day were developed. The barriers contain no metal foils, have a areal density of <34 g/m2 for a 40 micron thick film, and tolerate high temperature sterilization treatments. The polymer laminates are mechanically robust exhibiting a 165MPa yield strength, 200MPa tensile strength, 550MPa tensile modulus, and 3% elongation to yield. In Phase II, we propose to optimize barrier properties to reduce weight, minimize ash on incineration, develop heat-sealing methods, and expand the testing to include heat sealed enclosures. The Phase II effort also includes a collaboration with a potential high-volume **manufacturer** of the barrier films for aerospace applications.
SBIR	08	2	S1.01-9464	NNX10CB42C	EM4, Inc.	Efficient and Compact Semiconductor Laser Transmitter Modules	$599,889.00	Continue development of a Compact Transmitter Module (CTM). Modules will be voltage controlled to adjust wavlength using temperature and drive current settings. The electronics will be designed to be space qualifiable. Modules will be designed and **manufactured** capable of operating at 1.2x µm and 1.57 µm. Reductions in size, weight and power will be pursued using either small conventional coolers or thin film thermoelectric coolers (nano-coolers) to replace the conventional larger TEC. Weight reductions will be explore by using alternative which are composites of Aluminum Silicon (AlSi) and Aluminum Graphite.
SBIR	08	2	S5.03-8527	NNX10CA88C	Futek Advanced Sensor Technology, Inc.	Space/Flight Operable Miniature Six Axis Transducer	$599,995.00	FUTEK will fully design and **manufacture** a sensor capable of measuring forces in and about each axis. The unit will measure forces up to 300 Newton's in the principle axes and measure moment forces about each axis up to 50 Newton meters. The overall design will be optimized for a multitude of applications in many different environments. As a result, the unit is capable of surviving temperatures ranging from -135^oC and 125^oC and will remain operable within specification between -80^oC and 70^oC. In addition, the sensor will be designed to accommodate vacuum conditions and all components will be covered with a protective coating. To further improve the unit, the size and weight has been minimized, making the sensor more ideal for dynamic applications and less obtrusive in assembly design. During the phase 1 contract, FUTEK has developed two operating prototypes to prove concept and feasibility. Also, different adhesives and coatings have been successfully tested beyond the survival temperatures expected in most applications. However, a continuation into phase 2 will be necessary to optimize the final design and meet all specifications and requirements. The design will be optimized to support specified loads with an acceptable factor of safety, while components are further researched and selected. In addition, the **manufacturability** and market of the product will be analyzed and assessed in order to commercialize such an advanced sensor.

SBIR	08	2	S1.02-9783	NNX10CA55C	Group4 Labs, LLC	A 10kWatt 36GHz Solid-State Power Amplifier using GaN-on-Diamond	$599,465.00	This Phase-II SBIR proposal proposes for the first time ever, the use of a new class of materials - Gallium Nitride-on-diamond - in the **manufacture** of very high power, high-temperature, Ka-band sc
SBIR	08	2	A1.02-8907	NNX10CB25C	JENTEK Sensors, Inc.	Micromechanical Models for Composite NDE and Diagnostics	$599,907.00	Modern aircraft (and next generation spacecraft) increasingly rely on composite components due to their excellent specific strength and stiffness, as well as improvements in costs and **manufacturing** quality. However, life management for composites is in its infancy compared to life management for metal structures. Limitations in the ability of standard nondestructive evaluation (NDE) methods to observe **manufacturing** quality and in-service damage evolution of composite structures may prevent designers from realizing their full potential. Current NDE practices are incapable of overcoming these limitations. Thus, a new framework and methodology is needed for high resolution imaging and tracking of **manufacturing** quality and damage evolution. The goal of this program is to enable assessment of the matrix, fiber, and bonding conditions for composites using a combination of detailed physics-based models, high resolution imaging, and controlled loading sources to isolate the composite characteristic of interest. Micromechanical models allow quantitative determination of composite constituent properties. This program focuses on magnetic field sensing (i.e., eddy-current) methods that can be combined with structural analysis to enhance the diagnostic capabilities of these NDE methods. JENTEK and MR&D are well-positioned to deliver this methodology in the form of commercial software and NDE equipment. We will also work with a major aircraft OEM to maintain our focus on practical solutions to high priority needs.

SBIR	08	2	X4.02-8428	NNX10CA23C	Materials Modification, Inc.	Multifunctional B/C Fiber Composites for Radiation Shielding	$600,000.00	Components of lunar habitat and crew modules in the lunar vehicle are constantly exposed to hazardous space conditions, such as ionizing radiation, electromagnetic interference, orbital debris, and solar flares. The safe functioning of crew and instruments and survivability require effective radiation protection. There is also the desire to reduce the weight of parts in Space missions. In Phase I, Materials Modification Inc. developed a series of novel multifunctional composites using a proprietary high-hydrogen epoxy incorporating boron and carbon fiber layers with enhanced radiation shielding, structural, thermal and electrical properties compared with high density polyethylene (HDPE). Radiation shielding of B/C composites against high-energy neutrons were measured. The boron composites had approximately the same shielding effectiveness as HDPE and aluminum for the energetic neutrons. This is remarkable since the multifunctional properties of these hybrid boron/carbon fiber composites offer so much more than the overall properties of HDPE or Al, especially in the area of lightweight structural applications for aerospace. In Phase II, a series of composite laminates with a range of %B will be fabricated using unidirectional boron fiber and unidirectional carbon fiber in a non-autoclave process. Mechanical properties of the most promising composite compositions, including lamina and laminate properties at cryo temperature, RT, and elevated temperature will be determined. Radiation shielding studies with energetic charged particles such as, protons, heavy ions, and neutrons that would simulate conditions encountered in space will be performed. By the end of the Phase II, we would have **manufactured** and tested several compositions that provide optimum radiation shielding. We plan to address specific NASA mission requirements with our partners Boeing, Raytheon and Lockheed Martin who have expressed great interest in the results of the Phase I effort.
SBIR	08	2	A1.01-9133	NNX10CB24C	Nanosonic, Inc.	Hydrophobic Polymers with Adherend Complexing Sidechains as Durable Aerospace Adhesives	$600,000.00	In support of NASA Aeronautics Research Mission Directorate and Aviation Safety Mission, NanoSonic has developed a series of moisture and corrosion mitigating, ultra-hydrophobic, environmentally tunable, nanophase separating adhesive modifiers and complementary high performance, wide service temperature range (-60C to 450C) structural adhesives. The smart nanostructured modifiers represent a significant discovery as the adhesion strength of our novel and commercial-off-the-shelf aerospace adhesives was increased by > 40% with inclusion of such systems upon aging in 100% relative humidity (RH), ten days, 140F. Of significant importance to **manufacturability** and dual-use commercialization, the novel modifying agents are inert, inorganic-organic, halogenated hybrid copolymers, and hence can be used with virtually any adhesive, paint or environmental aerospace materials systems. The inorganic poly(octahedral silsesquioxane) (POSS), fluorination and copolymer molecular weight can be synthetically engineered to complement any paste of film adhesive. The TRL of the novel adhesive system would be increased from 6-8 during Phase II.

SBIR	08	2	A2.09-8605	NNX10CB33C	Nanosonic, Inc.	Metal Rubber Sensor Appliqu¿s for Rotor Blade Air	$600,000.00	Thin film Metal RubberTM sensor appliqués have the potential to reduce the time, complexity and cost of measuring air flow-induced skin friction during the development of rotary wing and fixed wing aircraft and related systems. Metal Rubber^{TM} skin friction sensor appliqués allow near real-time detection 2D mapping of air flow conditions over surfaces of air vehicles. This is important for analysis of laminar to turbulent flow transitions, flow separation and reattachment mechanisms, and other instabilities, during rotor blade and fuselage design, blade tracking adjustments, and active flight control. The sensors act as mechano-electrical transducers to convert air flow-induced tangential surface forces into electrical output signals. They are thin and surface-mounted so cause minimal interaction with the flow, are easy to apply as an appliqué, and require no cavities or recesses other than holes to connect the sensor leads to data acquisition wiring. The material is resistant to normal aircraft fluids and solvents, can operate over a temperature range of -65 to +150C, and is capable of withstanding moderate rain and dust erosion. During Phase II, NanoSonic will Â Develop an improved understanding of the operation of thin film Metal RubberTM skin friction sensors, Â Standardize sensor design and sensor fabrication processes, Â Develop a method to calibrate sensor elements as part of **manufacturing**, Â Develop a means to compensate for cross-sensitivity effects, Â Develop and optimize means for data acquisition, Â Use developed sensors in cooperation with the NASA LaRC Subsonic Rotary Wing program to investigate rotorcraft research and development problems, and Â Use and demonstrate the sensors in cooperation industry and academic colleagues. The significance of the proposed NASA Phase II SBIR program is in transitioning these sensors from analytical and FEM modeling to commercial products for experimental use by NASA and industry.
SBIR	08	2	S1.03-9640	NNX10CA78C	NxGen Electronics, Inc.	Low Cost Automated Module Assembly for 180 GHz Devices	$595,451.00	Despite the obvious advantages of millimeter wave technology, a major barrier to expanded use is high assembly costs due to: need for specialized equipments; need for precision impacts on yields; design technologies for **manufacturability**; and experienced personnel with demonstrated track records. The challenges of this R&D project are to expand and fully develop the Phase 1 technologies for: Methods to use common **manufacturing** equipment to achieve the high accuracy die placement required for millimeter wave frequencies (+/- 5 micron accuracy) Automation methods and processes to achieving speed and precision for production of low cost modules Modeling to arrive at cost effective trade-offs for achieving customer specifications with minimum capital investment and labor cost As part of the research, NxGen will conduct a demonstration effort utilizing two existing JPL module designs facilitating the collection statistical data both in terms of yields as well as baseline data for cost estimating.

SBIR	08	2	S2.04-9652	NNX11CA02C	Optical Physics Company	Silicon Carbide Lightweight Optics With Hybrid Skins for Large Cryo Telescopes		Optical Physics Company (OPC) has developed new silicon carbide (SiC) foam-based optics with hybrid skins that are composite, athermal and lightweight (FOCAL) that provide an enabling capability for performing NASA space missions that will require 2 to 3 meter class cryogenic mirrors for infrared telescopes. The key development in the Phase I program was the replacement of OPC monolithic SiC skins with SiC fiber reinforced/SiC CVD hybrid skins on 1.5" coupons, 4" flat and then 12" powered optics. This innovation avoids scale-up problems that include the inherent stress in the monolithic skins which can result in skin cracking during the substrate **manufacturing** and finishing processes, the non-uniformity of the .040"-.050" thick monolithic skins that typically require .010"-.015" of material removal before a continuous surface can be achieved for optical finishing, the long schedule of **manufacturing** the mirror substrate, and the large $2M/m2 cost to produce the polished mirror. The hybrid skin technology provides increased skin strength and toughness to enable the foam based technology to produce meter class mirrors without skin cracking. The **manufacturing** time and CVD chamber cost are reduced because **premanufactured** SiC fibers are used to provide the bulk of the skin mass rather than laying down a monolithic skin atom by atom via CVD. The net effect is to produce a SiC FOCAL mirror substrate that is stronger, tougher, scalable to meter class, and potentially better than 50% faster and cheaper to **manufacture**. OPC proposes to demonstrate that the hybrid skin technology developed in Phase I can be successfully applied to **manufacture** a 22" diameter F/2 spherical SiC FOCAL hybrid skin substrate and then polish it into a precision mirror on a Phase II program.
SBIR	08	2	S1.08-9758	NNX11CA01C	Opto-Knowledge Systems, Inc. (OKSI)	A Miniaturized UV/VIS/IR Hyperspectral Radiometer for Autonomous Airborne and Underwater Imaging Spectroscopy of Coastal and Oceanic Environments		The AquaScan, a miniaturized UV/VIS/NIR hyperspectral imager will be built for deployment on a UAV or small manned aircraft for ocean coastal remote sensing applications. The hyperspectral system includes a data acquisition system with remote operation capability proving a real-time waterfall display of the hyperspectral scans. OKSI teamed with Scripps Institution of Oceanography to define and design a sensor that explicitly meets the performance requirements needed for ocean remote sensing of coastal regions, but can also be used for terrestrial remote sensing. Specifically, some key requirements called for: 1) high spatial resolution (< 1 meter), 2) high spectral resolution (< 10 nm), UV Å NIR coverage (300 Å 1000 nm), 4) high sensitivity for low reflectivity of ocean surfaces, 5) provide simultaneous downwelling solar radiation measurements, and 6) allow for operating mode that avoids specular reflections off ocean surface. The AquaScan design was completed during the Phase I effort. During Phase II the sensor will be **manufactured**, tested, calibrated, and prepared for flight testing. The system will then be demonstrated during several airborne tests off the Southern California coast. The tests will include measurements of spatially/spectrally unique ocean phenomena including red tide blooms and river plume run-offs after heavy rain storms. Coordinated ship-based remote sensing and in situ measurements will take place concurrently with the newly developed miniature UV/VIS/NIR airborne measurements. The ship-based measurements will serve as ground truth for validation/verification. In addition, OKSI will attempt to coordinate data collections with satellite passes (e.g., MODIS, MERIS, SeaWiFS). Comparison with satellite data will serve as validation and demonstration of the capability to support future satellite programs (e.g., GEO-CAPE).

SBIR	08	2	X6.02-9113	NNX10CA51C	Physical Sciences, Inc.	Silicon Whisker and Carbon Nanofiber Composite Anode	$600,000.00	Physical Sciences Inc. (PSI) has successfully developed a silicon whisker and carbon nanofiber composite anode for lithium ion batteries on a Phase I program. PSI has demonstrated a technology readiness level of 3 with an anode composite capacity of greater than 1100 mAh/g for over 200 cycles (100% depth-of-discharge) at 1C using 2 mAh cells. This anode provides high capacity, high power, and improved cycle life at a competitive cost. Silicon is low cost and has a theoretical capacity of 4200 mAh/g but it has a limited cycle life. The nanocomposite design provides a synergistic improvement in reversible capacity and electrochemical cycling as a result of the unique silicon architecture and structural reinforcement provided by the nanofibers. In the Phase II program, PSI will increase cell size to 2.5 mAh and optimize cell design to further improve cycle life. PSI will deliver to NASA 2.5 Ah lithium ion cells with an energy density greater than 220 Wh/kg that is required by NASA's future robotic and human exploration missions. In collaboration with a battery **manufacturer**, PSI will also demonstrate that this anode technology is scaleable to reach industrial production level.
SBIR	08	2	X3.03-9828	NNX10CA45C	Pioneer Astronautics	Lunar Soil Particle Separator	$599,827.00	The Lunar Soil Particle Separator (LSPS) is an innovative method to beneficiate soil prior to in-situ resource utilization (ISRU). The LSPS can improve ISRU oxygen yield by boosting the concentration of ilmenite or other iron-oxide bearing materials found in lunar soils. This can substantially reduce hydrogen reduction reactor size and drastically decrease the power input required for soil heating. LSPS particle size separations can be performed to de-dust regolith and to improve ISRU reactor flow dynamics. LSPS mineral separations can be used to alter the sintering characteristics of lunar soil. The LSPS can also be used to separate and concentrate lunar minerals useful for **manufacture** of structural materials, glass, and chemicals. The LSPS integrates an initial centrifugal particle size separation with magnetic, gravity, and electrostatic separations. The LSPS centrifugal separation method overcomes the reduced efficiency of conventional particle sieving in reduced gravity. The LSPS hardware design integrates many individual unit operations to reduce system mass and power requirements. The LSPS is applicable to ISRU feed processing as well as robotic prospecting to characterize soils over wide regions on the Moon. The LSPS is scalable and is amenable to testing and development in vacuum and reduced gravity.
SBIR	08	2	X3.02-9756	NNX10CB20C	Plasma Processes, LLC.	High Surface Area Iridium Anodes and Melt Containers for Molten Oxide Electrolysis	$600,000.00	Direct electrochemical reduction of molten regolith is the most attractive method of oxygen production on the lunar surface, because no additional chemical reagents are needed. The process is proven on a laboratory scale, but the cathode-anode system and melt containers need to be improved for practical applications. The electrochemical processing of molten oxides requires high surface area inert anodes. Such electrodes need to be structurally robust at elevated temperatures (1400-1600^oC), resistant to thermal shock, have good electrical conductivity, resistant to attack by molten oxide (silicate), electrochemically stable, and support high current density. Iridium is a proven material for this application. Innovative concepts for large scale, high surface area iridium anodes and long life, self-heating containers for the melts are proposed. The result of this program will be the development, **manufacture**, and test of high surface area iridium anodes and melt containers for molten oxide electrolysis to produce oxygen.

SBIR	08	2	S1.01-9781	NNX10CB44C	Princeton Optronics, Inc.	A High Reliability Frequency Stabilized Semiconductor Laser Source	$599,999.00	Ultrastable, narrow linewidth, high reliability MOPA sources are needed for high performance LIDARs in NASA for, wind speed measurement, surface topography and earth and planetary atmosphere composition measurements. Princeton Optronics is developing a MOPA laser source for these applications. Phase I experiments concluded that the optimum approach will use a DPSS microchip laser with the SOA. This would provide a MOPA source with narrow linewidth, <10kHz, and an output power of 1W. The Phase II program would develop the MOPA laser technology and build prototypes for testing in NASA. These prototypes would be ready for final engineering test and **manufacture**. The microchip laser will be upgraded to incorporate our patented noise reduction technology to suppress RIN. This reduces noise >55dB in our Telecom tunable lasers. This would provide a seed laser with 1kHz linewidth, low RIN and >10mW power. The SOA designed in Phase I would be developed for 1W output power in the 1550nm band. Filtering will be incorporated to minimize noise and linewidth broadening. Bench experiments will be performed to determine optical configuration for the final rugged package design. Packaged prototypes will be built and tested. Final prototypes will be built and available to NASA laboratory for testing.
SBIR	08	2	A2.01-8646	NNX10CA30C	Shape Change Technologies	Development of Fast Response SME TiNi Foam Torque Tubes	$599,456.00	In Phase I, Shape Change Technologies had developed a process to **manufacture** net shape TiNi foam torque tubes that demonstrated the shape memory effect. The torque tubes dramatically reduce the response time by a factor of 10 and with integrated hexagonal ends, make structural connections fascile. In Phase II we see to mature this actuator technology by rigorously characterizing the process to optimize the quality of the TiNi and develop a set of metrics to provide ISO 9002 quality assurance. With the rapid response time, a Labview based real time control of the torsional actuators will be developed. With team partner Boeing, we will develop these actuators for aerospace applications and Boeing will independently characterize the actuators.
SBIR	08	2	X6.02-8492	NNX10CA50C	Superior Graphite Co.	SiLix-C Nanocomposites for High Energy Density Li-ion Battery Anodes	$599,888.00	For this project Superior Graphite Co. (Chicago, IL, USA), the leading worldwide industrial carbon **manufacturer** and the only large scale battery grade graphitic carbon producer in the USA, will develop, explore the properties of, and demonstrate the enhanced capabilities of novel nanostructured SiLix-C anodes, capable of retaining high capacity at a rapid 2 hour discharge rate and at 0oC when used in Li-ion batteries. By thye end of Phase I we have demonstrated advanced anode materials with the specific capacity in excess of 1000 mAh/g, minimal irreversible capacity losses and stable performance for 20 cycles at C/1. We are confident that by the developing and applying a variety of novel nano-materials technologies, fine-tuning the properties of composite particles at the nanoscale, optimizing the composition of the anodes, and choosing appropriate binder and electrolytes we will be able to revolutionize Li-ion battery technology. In order to achieve such a breakthrough in power characteristics of Li-ion batteries, the team will develop new nanostructured SiLix-C anode materials to offer up to 1200 mAh/g at C/2 at 0oC and a long cycle life with less than 20% fading when cycled for 2000 cycles at C/2 at 0oC

SBIR	08	2	O3.03-9387	NNX10CB17C	TDA Research, Inc.	Low Toxicity Corrosion Inhibitors for Smart Coatings	$600,000.00	The Kennedy Space Center maintains approximately $2 billion worth of ground support facilities to support its launch vehicle program. Maintenance of the ground facilities is a difficult and ongoing task since the Kennedy Space Center (KSC) is located in one of the most aggressive corrosion environments in the U.S. The effects of the corrosive environment at the KSC are compounded by the exhaust of the Space Shuttle's solid rocket boosters which produce an estimated 17 tons of hydrochloric acid with each launch. The Phase II project will continue the development of the models began in Phase I for classification of corrosion inhibitors for structural steel. We will produce even more robust models for selecting synergistic corrosion inhibitor compositions through a sequential program of algorithm development and high throughput electrochemical screening. We will then demonstrate the efficacy of the new compositions in protective coatings by electrochemical impedance studies, cyclic corrosion tests and outdoor exposures. In addition we will also develop toxicity classification tools for organic corrosion inhibitors. We will also scale up production of the corrosion inhibitor additive packages for evaluation by coating **manufacturers**.
SBIR	08	2	X6.01-8889	NNX10CA48C	Thermacore, Inc.	Titanium Heat Pipe Thermal Plane	$598,709.00	The objective of the Phase II program is to complete the development of the titanium heat pipe thermal plane and establish all necessary steps for production of this heat pipe. The main aerospace application for this titanium heat pipe design is fuel cell thermal management. Electronics cooling is expected to be the largest commercial market for this technology. The Phase I program was successfully completed five weeks sooner than deadline. All main technical objectives were met. Three thermal plane units were produced and thermally tested. One unit was shipped to NASA GRC and one unit is currently in a "burn-in" setup for Non-Condensable Gas (NCG) generation prevention. NCG generation still remains the most important issue to be resolved before heat pipe will be ready for production. Another limiting factor for wide commercial application of the titanium heat pipes is their high **manufacturing** cost. These issues will be addressed in the Phase II program. The Phase II work effort is divided into eleven tasks: ten technical tasks plus one reporting task. The work involves reviewing requirements, thermal plane design, alternative materials development, design optimization, non-condensable gas abatement concluding with the fabrication test and delivery of several titanium thermal planes to NASA. All tasks will be accomplished at Thermacore, Inc. facility.

SBIR	08	2	X4.06-9473	NNX10CA24C	Touchstone Research Laboratory, Ltd.	Carbon Foam Self-Heated Tooling for Out-of-Autoclave Composites Manufacturing	$599,999.00	Touchstone Research Laboratory, Ltd. (Touchstone) has developed a novel and innovative Out-of-Autoclave (OOA) composites **manufacturing** process with an electrically heated carbon foam tooling system. Electrically Heated Tooling (EHT) utilizes a coal-based carbon foam (CFOAM^{REG}) core that serves as both the tool substrate and the heating source for a composite part being cured. The tool heating is a result of flowing current through the carbon foam, which results in heating. This approach to self-heated tooling is a potentially enabling technology for **manufacturing** large composite structures by eliminating the need for autoclaves and large curing ovens, as well as by reducing costs, weight, and improving composite part quality. The overall objective of the NASA Phase 2 program will be to optimize critical factors for thermal uniformity in a CFOAM Electrically Heated Tool (EHT) and to validate the electrically heated cure process with current state-of-the-art OOA materials. The data generated will be used to produce a Scaled Composite Shroud (SCS) cylindrical mandrel EHT that will be designed, fabricated, tested, and used to cure a large composite part without an autoclave or oven. The SCS demonstration tool will be up to an 8' diameter and 12' length mandrel, which will be approximately one-forth of the scale as a tool necessary for an ARES V composite structure.

Program	Program Year	Phase	Proposal#	Contract#	Firm Name	Proposal Title	Award Amount	Proposal Abstract
STTR	08	2	T4.01-9937	NNX10CB62C	ADVR, Inc.	Ridge Waveguide Structures in Magnesium-Doped Lithium Niobate	$599,957.00	AdvR, Inc. proposes the development of an efficient process for fabricating ridge waveguides in magnesium-doped lithium niobate (MgO:LN). The effort will include, but will not be limited to, fabricating ridge waveguides in periodically poled MgO:LN for highly efficient, single-pass, quasi phase-matched frequency conversion. Ridge waveguides in MgO:LN will significantly improve the performance (power handling and conversion efficiency), increase photonic component integration, and be well suited to space based applications. The key innovation in this effort is to combine recently available large, high photorefractive damage threshold, z-cut 5% MgO:LN with novel ridge fabrication techniques to achieve high optical power, low cost, high volume **manufacturing** of frequency conversion structures. The ridge waveguide structure maintains the characteristics of the periodically poled bulk substrate, allowing for the efficient frequency conversion typical of waveguides and the high optical damage threshold and long lifetimes typical of the doped bulk substrate.
STTR	08	2	T8.01-9965	NNX10CB69C	TXL Group, Inc.	Shockwave Fabrication of High Performance Thermoelectrics	$600,000.00	Thermoelectric (TE) generators have the advantages of no moving parts and flexibility in deployment but suffer from low heat to electricity conversion efficiencies, with a major loss component being conductive (phonon) heat transfer through the TE lattice. By using a high pressure shockwave consolidation, nanopowders can be fused into a solid bulk TE material while preserving the nanostructure. The high density of grain boundaries and lattice defects impedes phonon transport while allowing electron flow. Specific Phase 2 research thrusts will be directed at transitioning laboratory fabrication into volume **manufacturing**, at producing a graded thermoelectric that is optimized for different temperature ranges over the length of the element, and at preparing bulk thermoelectric material from transition metal trichalcogenides that are not appropriate for melt or powder sintered fabrication. The overall conversion efficiency of a TE device will always be limited by the Carnot ratio of (Th-Tc)/Th, where Th and Tc are the temperatures of the hot and cold junctions. With the restrictions on phonon transport accruing from nanopowder consolidation, conversion efficiencies in excess of 30% of the Carnot limit are reasonable.

Phase III Contract #	Phase III Fiscal Yr	Phase II Contract #	Prog Yr	Firm	Phase III Project Title	Award Amount	Phase II Abstract
NNC10CA19C	10	NAS3 02160	01	A&P TECHNOLOGY	Affordable Composite Fan Containment Case with Integral Toughening Elements	$ 59,397.00	The proposed program will develop and demonstrate an affordable **manufacturing** approach to fabricate the latest generation of damage tolerant composite fan case designs. These designs embed a grid of stiffener ribs within the composite laminate to limit damage propagation that is initiated during the fan blade containment event. This grid blunts the crack growth and restricts damage within a "safe zone" that permits structural viability of the case after the blade is contained. The proposed work package will demonstrate that advanced braiding concepts can be used to fabricate these composite-toughening elements in a cost-effective manner. This economically viable fabrication method will allow widespread application of the toughened design concept and enable weight efficient, safe containment system designs for high bypass turbofan engines.

2010 SBIR Spinoff Successes

Lightweight Material Patches Allow for Quick Repairs

Originating Technology/NASA Contribution

Here on Earth, if your sink springs a leak, you can call in a plumber, or if you're handy, you can head out to the local hardware store, buy a few replacement parts, and fix the problem yourself. If the leak isn't particularly bad, you can even place a bucket under the sink to catch the dripping water and put the chore off until the weekend. These options aren't exactly available to astronauts working on the International Space Station. They can't call in a specialist to make repairs when problems occur, and they can't run out to the hardware store for the exact parts needed for a repair. Plus, there isn't much free time in an astronaut's onboard schedule. Repairs need to be made as soon and as efficiently as possible. Toward that end, NASA funded the design of simple and reusable patch repair systems for servicing, maintaining, and repairing structural components in space without the need for heavy machinery or an expense of time.

Partnership

Cornerstone Research Group Inc. (CRG), of Dayton, Ohio, works in a variety of fields to produce high-tech solutions and provide technology development services. CRG specializes in transitioning new ideas from the laboratory to the market, which made it a good fit for working with NASA. It has been the recipient of 16 **Small Business Innovation Research (SBIR)** contracts with NASA, with a variety of different focuses, including projects like creating inflatable structures for radio frequency antennas and, most recently, healable polymer matrix composites for future space vehicles. One of its earlier SBIR contracts, with Kennedy Space Center, led to the development of a new type of structural patch for a variety of consumer uses. While this particular project only ran through a Phase I contract with NASA, according to CRG's Brenda Hood, "So much happened during that initial Phase I research that we knew we had a product with a lot of commercial value."

Rec'Repair is a tough, formable patch for easily repairing holes and damage to aluminum, steel, other metals, fiberglass, glass, painted surfaces, plastic, some wood, stiff vinyl, copolymers, and composites.

CRG Industries LLC, of Dayton, Ohio—a spinoff company of Cornerstone designed to manufacture and distribute the state-of-the-art materials developed by its parent company and specializing in moving the advanced research into the consumer markets—has commercialized the NASA-derived material under two trademarked names: Rubbn'Repair, for automotive uses; and Rec'Repair for the outdoors and adventure market.

Product Outcome

The Rubbn'Repair patch is tailored for automotive use, providing rigid, strong repairs for holes and damage to body panels, fenders, and bumpers, with the capability to even replace missing structural or body material. Once the adhesive patch is heated to approximately 194 °F, it becomes flexible and moldable and can be applied to the damaged area. When the material cools—in seconds—it becomes a rigid structural patch.

In auto racing applications, where the cars are exposed to constant stresses and repairs need to be conducted as quickly as possible, the patch makes for an ideal temporary fix. Since the adhesive can be heated multiple times, pit crews can store the nontoxic patches ready for use, continually applying moderate heat to keep the product flexible until use. Once the patch is applied, the car can be back on the track in a matter of seconds, with the patch able to withstand the vibrations and stresses of high speeds. The Rubbn'Repair patch is a structural composite, and unlike typical racing tape, will not degrade and delaminate at high speeds, providing a quick option for restoring aerodynamic shaping and preventing further damage.

It is also available for use in standard auto repair, where once it has been applied, the material can be machined and painted, providing a structural alternative to the thin patches usually used in bodywork. It can also be used behind a bumper, providing rigid adhesion and structure while a hole is repaired with conventional fillers. Once cured, the patch will not degrade, crack or crumble; it is waterproof, UV-resistant, vibration resistant, and can withstand typical weather-related temperature fluctuations. Rubbn'Repair has been particularly embraced by the trucking industry, where quick repairs on the road allow goods to be delivered on time, and pulling over on the side of the road to patch a leak in a refrigerated truck's insulation or hold a broken piece of fender on long

Heated to about 194 °F, the material becomes flexible and moldable to any repair surface. As it cools, it becomes rigid again and retains the new shape. At operating temperatures, the material is rigid and strong.

The patch becomes rigid after it is shaped and then cooled, creating a durable, water-resistant, structural repair that does not crumble or peel.

enough to get the product delivered is highly preferable to stopping for professional repair.

Based on the same technology, CRG created another application for the composite material: a portable patch for a variety of outdoors and emergency applications. Rec'Repair is a fully cured repair patch, consisting of high-tensile fabric, the patented shape-changing resin, and an industrial-strength adhesive surface on one side. When heated, the patch becomes pliable and can be shaped to fit a wide assortment of angles. The patch becomes rigid when it cools, providing a water- and weather-resistant solution that is stronger than duct tape, and takes fewer than 10 minutes to apply.

Rec'Repair is designed to meet the needs of campers, boaters, vacationers, and adventurers when they need an emergency, temporary structural patch, whether it is for a cooler, fishing rod, or even the bottom of a canoe. It is lightweight and easily packed and carried, and allows for broken or damaged gear to be repaired on the fly, with little delay.

Low levels of heat, such as those provided by a hot air gun or even a short period in the microwave, are enough to make the patch flexible. For field use, though, the patch comes with a water-activated heating pouch similar to those used in military "Meal, Ready to Eat" (MRE) packaging that, in 10 minutes, warms the patch enough to become flexible for application. Once the patch is flexible, the user removes the adhesive backing, and then applies the patch to the desired area, pressing firmly with just hand pressure. After the patch cools, the damage is repaired.

Applications for this space-derived, portable, moldable patch are nearly limitless. According to Hood, "People know that NASA conducts a lot of high-tech, cutting-edge experimental work, and that oftentimes products develop out of this work. This is one of those products." ❖

Rec'Repair® and Rubbn'Repair® are registered trademarks of Cornerstone Research Group Inc.

The patches are capable of withstanding extreme cold without breaking down.

Innovative Techniques Simplify Vibration Analysis

Originating Technology/NASA Contribution

As the launch clock counts down, astronauts in the space shuttle prepare for the fastest ride of their lives. More powerful than any plane, train, or automobile, NASA space shuttles boast the world's most sophisticated rocket engines: three 14-foot-long main engines that produce more than 375,000 pounds of thrust each. This thrust is approximately four times that of the largest commercial jet engine—and produces an extreme amount of vibration.

In the early years of development, Marshall Space Flight Center engineers encountered challenges related to the development of engine components in the space shuttle main engine (SSME). To assess the nature of these problems, the engineers evaluated the system's components and operating environment, including the effects of vibration and oscillation. Similar to examining a patient's heartbeat and blood pressure to inform a medical diagnosis, engineers measure vibrations to diagnose mechanical issues. At the time, vibration signal analysis was a costly, tedious, and time-consuming process. It required an expansive in-house computer system along with several dedicated personnel to keep it functioning.

"A number of significant hardware failures on the SSME necessitated the need for more sophisticated and advanced diagnostic analysis techniques to be developed," says Jess Jones, a retired NASA engineer and a senior staff engineer at AI Signal Research, Inc. (ASRI) in Huntsville, Alabama.

Partnership

By the 1990s, the power of personal computers advanced significantly, and Marshall awarded ASRI a **Small Business Innovation Research (SBIR)** contract to enhance the method of vibration signal analysis. Through follow-on SBIRs with Marshall, ASRI developed PC-SIGNAL, a software package with improved tools and techniques for vibration signal analysis to assess engine ground test and flight performance. For the first time, engineers could analyze vibration and oscillation data from the convenience of a laptop or personal computer.

The new techniques allowed for quick and easy identification of potential design issues related not only to vibration, but also related to other signals resulting from sound, strain, and fluid flow. Even though the amount of sophisticated data increased, PC-SIGNAL simplified the analysis of it. According to Dr. Jen Jong, the chairman and director of research and development at ASRI, "Signal analysis had been limited to time, frequency, and phase domains, but PC-SIGNAL offered advanced

Space Shuttle Endeavour concludes a mission at Dryden Flight Research Center in 1992. The three liquid-propelled main engines, seen at the back of the vehicle, help to power the shuttle into low Earth orbit.

"Partnering with NASA provided a unique opportunity to work on challenging technical problems."

signal analysis at various other domains. This information provided further insight into the engine's operating conditions."

One of PC-SIGNAL's unique modules, PKP-Module, reconstructs speed signals directly from external vibration measurements, without the installation of intrusive speed sensors. This enables additional vibration analysis techniques for the SSME.

"Partnering with NASA provided a unique opportunity to work on challenging technical problems, which in turn stimulated research and development of innovative solutions to real-world problems. It allowed ASRI to participate in the advancement of state-of-the-art techniques in many critical engineering areas," says Jong.

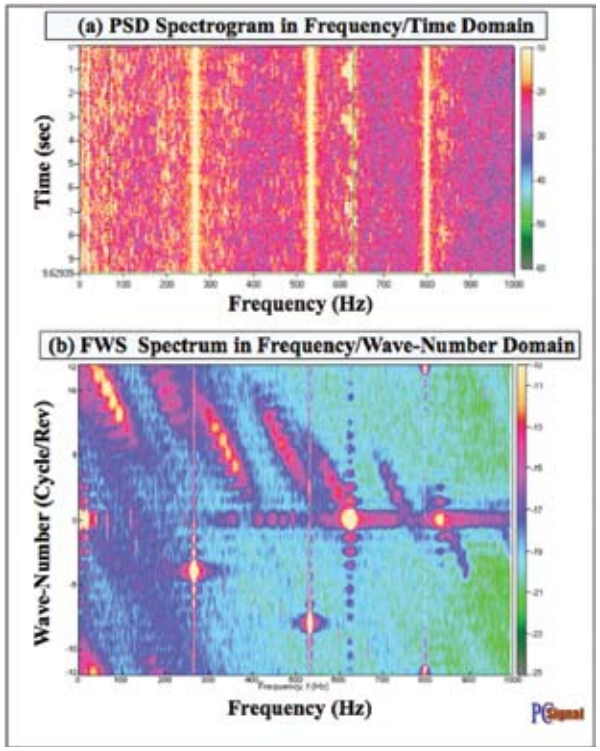
Today, NASA employs PC-SIGNAL on a daily basis for development and testing of propulsion systems. It is used for processing dynamic data and other diagnostic analysis, such as analyzing engine health data from shuttle missions, flow testing to identify and resolve fluctuations in pressure in turbopumps, and in designing new rockets. Most recently, the software helped to resolve a cracking issue in a valve in the Space Shuttle Endeavor's main propulsion system.

Due to the technology's benefits to space flight missions, the PKP-Module won Marshall Space Flight Center's "Software of the Year" award in 2009. That same year, the PKP-Module received a Space Act Award in the exceptional category by the Inventions and Contributions Board of NASA.

Product Outcome

With its roots in software development for NASA, ASRI has grown over the last 20 years to provide diverse engineering, programmatic and technical services not only to NASA, but also to the U.S. Department of Defense (DoD) as well as commercial customers. Today, there are more than 80 users of PC-SIGNAL who are enhancing mechanical design and development efforts across the country.

Made to use on a personal computer in a Microsoft Windows-based environment, the graphical user interface of PC-SIGNAL makes it easy to use, and the automated capabilities save time when analyzing large amounts of data. It can view signal properties at various domains through two-, three-, or four-dimensional displays. As Jong explains, "All of the mathematical routines, filtering, and enhancement processes to reduce unwanted noise and other signal contamination are built into the programs. There is no additional programming necessary. Just point and click."



PC-SIGNAL created these dynamic displays of the signal properties in a space shuttle main engine.

The software features a number of specialized techniques for engine and machinery diagnostic evaluation including vehicle bearing, gearbox, and drive train signal analysis. Applications include dynamic signal analysis, system health monitoring, flight data analysis, flow data analysis, and fatigue analysis and monitoring. The main markets are the aircraft and helicopter industries, rocket engine manufacturers, the transportation industry, and the nuclear power industry.

DoD employs PC-SIGNAL to calculate data about vehicle and helicopter components and materials including vibration specification development and fatigue analysis and monitoring. The U.S. Army Redstone Test Center uses PC-SIGNAL for vibration data processing and for developing specifications for its weapon system test programs.

The U.S. Air Force Research Laboratory has also applied PC-SIGNAL for vibration analysis in engine testing. Aside from government use, large aerospace firms such as Pratt & Whitney and Aerojet have purchased licenses from ASRI to use PC-SIGNAL for rocket and jet engine development, as well as for testing and analyzing the fluid flow in turbopumps.

While current applications of the software are largely focused on vibration analysis, opportunities exist for wider application of dynamic signal analysis in test facilities and laboratories. In the future, ASRI plans to provide a low-cost, portable, easy-to-use, real-time version of PC-SIGNAL for dynamic signal analysis, also based on the NASA-funded technology. ❖

Hand-Held Devices Detect Explosives and Chemical Agents

Originating Technology/NASA Contribution

Smaller, with enhanced capabilities. Less expensive, while providing improved performance. Energy efficient, without sacrificing capabilities. Smaller, less expensive, and energy efficient—but still highly durable under some of the most extreme conditions known.

Contradictions like these are commonplace when designing sensor instruments for spacecraft. The Curiosity Mars Science Laboratory, for example, is set to launch in 2011 with an anticipated 10 instruments onboard that must endure the launch, an 8-month journey to Mars, landing, and the unfriendly environment of the Red Planet. Packing that much scientific punch into a single, reliable, one-shot package requires the most advanced technology available.

Given the high cost of development and launch; the need for consistent, high-level operation in harsh conditions and without the possibility of maintenance; and the limited real estate available on a spacecraft; NASA continually seeks ways both to develop new sensor technology and to advance existing devices to meet the demands of space exploration—in many cases through collaboration with private industry. Sometimes, the effort results in smaller, less expensive, more energy efficient, and highly durable products for use on Earth, as well.

Partnership

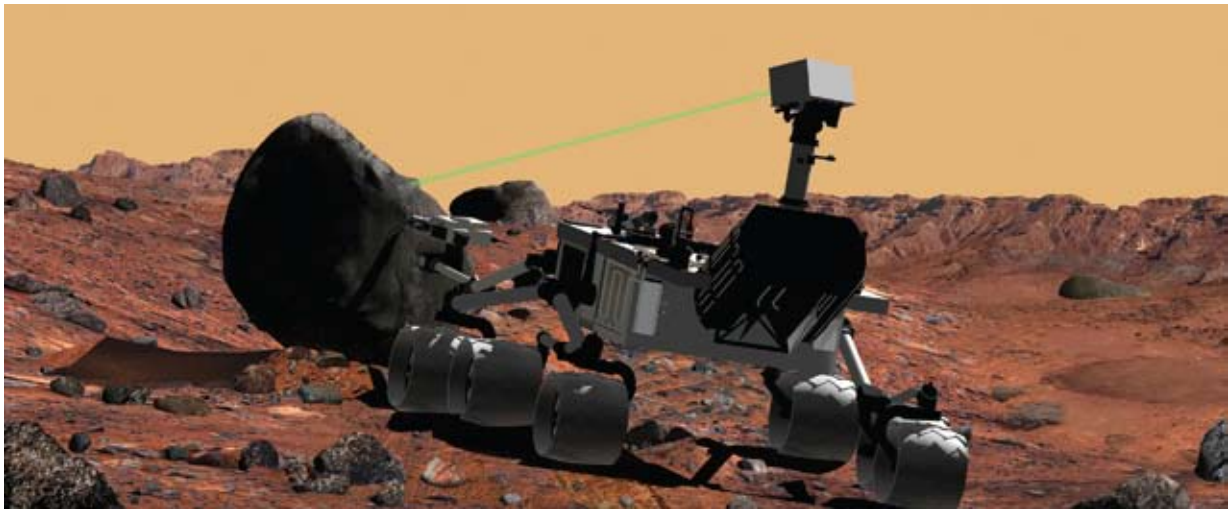
NASA's Astrobiology Science and Technology Instrument Development (ASTID) program encourages the development of innovative instruments equally capable of fulfilling astrobiology science requirements on space missions or related science objectives on Earth. Through ASTID and the **Small Business Innovation Research (SBIR)** program, Ion Applications Inc., of West Palm Beach, Florida, worked to meet NASA's need for a miniature version of a powerful sensor technology known as an ion mobility spectrometer (IMS).

Ion mobility spectrometry is a fast, highly sensitive method for separating and identifying gaseous molecules. In an IMS device, ionized molecules sampled from the air travel through a drift tube containing a buffer gas. The speed of travel is influenced by the ion's mass, size, shape, and charge. By measuring how quickly the ions migrate through the tube, IMS can identify a significant variety of molecules with part-per-billion sensitivity. The instrument displays lesser sensitivity toward other molecules, such as light hydrocarbons and noble gasses, under normal operating conditions.

"An IMS can basically detect almost anything, from heavyweight compounds all the way down to permanent gasses like hydrogen," says Alex Lowe, Ion Applications' vice president of sales and marketing. This capability makes IMS an obviously valuable detection instrument; in particular, it has been the technology of choice for explosives and chemical warfare agent detection since the 1960s and is in widespread use for airport security and military applications.

NASA had already developed a gas chromatograph ion mobility spectrometer (GC-IMS) called the mini-Cometary Ice and Dust Experiment (miniCIDEX). The device combines gas chromatography with ion mobility spectrometry to provide highly sensitive gas analysis for astrobiology missions. While the GC device had been successfully miniaturized, the IMS component needed to be smaller and capable of producing accurate readings with a reduced sample size. With SBIR support from Ames Research Center, Ion Applications developed a unique, miniature, Kovar (an alloy) and ceramic IMS cell; simplified electronics; and software for control and spectra acquisition.

The resulting Mini-Cell IMS proved to be a more sensitive, reliable, and rugged tool than existing IMS technology. For NASA, the improved IMS device could be used for future missions to planets, moons, and comets, or as a space-saving tool to monitor air quality on the International Space Station. On Earth, the applications are proving even more varied and beneficial.



The Mars Science Laboratory, shown in the rendering above, will carry an anticipated 10 scientific instruments, the most for a Mars rover to date. These instruments must be rugged and powerful while still being able to fit within limited space on the rover platform.

Product Outcome

Ion Applications has commercialized the Mini-Cell IMS in the form of its EASYTEC-XP hand-held detector. Housed in a pistol grip casing with a point-and-shoot sampling mechanism, the EASYTEC-XP solves many of the existing engineering problems surrounding IMS devices, including portability.

"The traditional IMS has some inherent field problems that don't make it user friendly from a continuous operations standpoint," Lowe says. Unlike typical IMS devices, EASYTEC-XP does not require membranes to keep out moisture and other ambient air interference. Its IMS cell is 10 times smaller and more sensitive, and the detector requires no calibration and has annual maintenance costs that are about 8 times less expensive than the standard. It also requires no swipes or contact to make measurements, making it an ideal tool for field use.

"The traditional IMS products out there that don't use our platform aren't well suited for a number of applications, either in terms of size, price, or convenience," Lowe says. "We can basically plug into those applications right away."

Currently, the U.S. Army and Navy are using the EASYTEC-XP for detection of explosives and chemical warfare agents. Soldiers can simply carry the tool to a vehicle, for example, to inspect it for trace explosives or other dangerous chemicals. The device is also in use by international law enforcement, and the company has developed a narcotics detector capable of detecting heroin, cocaine, methamphetamine, and THC. EASYTEC-XP's versatility, durability, and portable format render it useful for transportation security, port container inspection, general air monitoring, and other military and security applications.

EASYTEC-XP has uses beyond public safety, as well. Ion Applications' technology is employed in China for high-purity process gas analysis for semiconductor manufacturing. The IMS readily detects damaging moisture in the special gasses used during the manufacturing process. Other industrial applications include cleanroom air monitoring and the detection of toxic gasses produced during industrial processes.

Ion Applications is continuing work on a wide range of potential applications for its NASA SBIR-derived technology, Lowe says.

"This is a platform that is allowing us to put together many commercial products that were never before attractive from an IMS standpoint." ❖

Kovar™ is a trademark of Carpenter Technology Corporation.
EASYTEC®-XP is a registered trademark of Ion Applications Inc.

Requiring no calibration and no swipes or contact to make measurements, Ion Applications Inc.'s ion mobility spectrometer technology can inspect packages and vehicles for trace explosives and other dangerous chemicals. The device is in use by the U.S. military and international law enforcement.

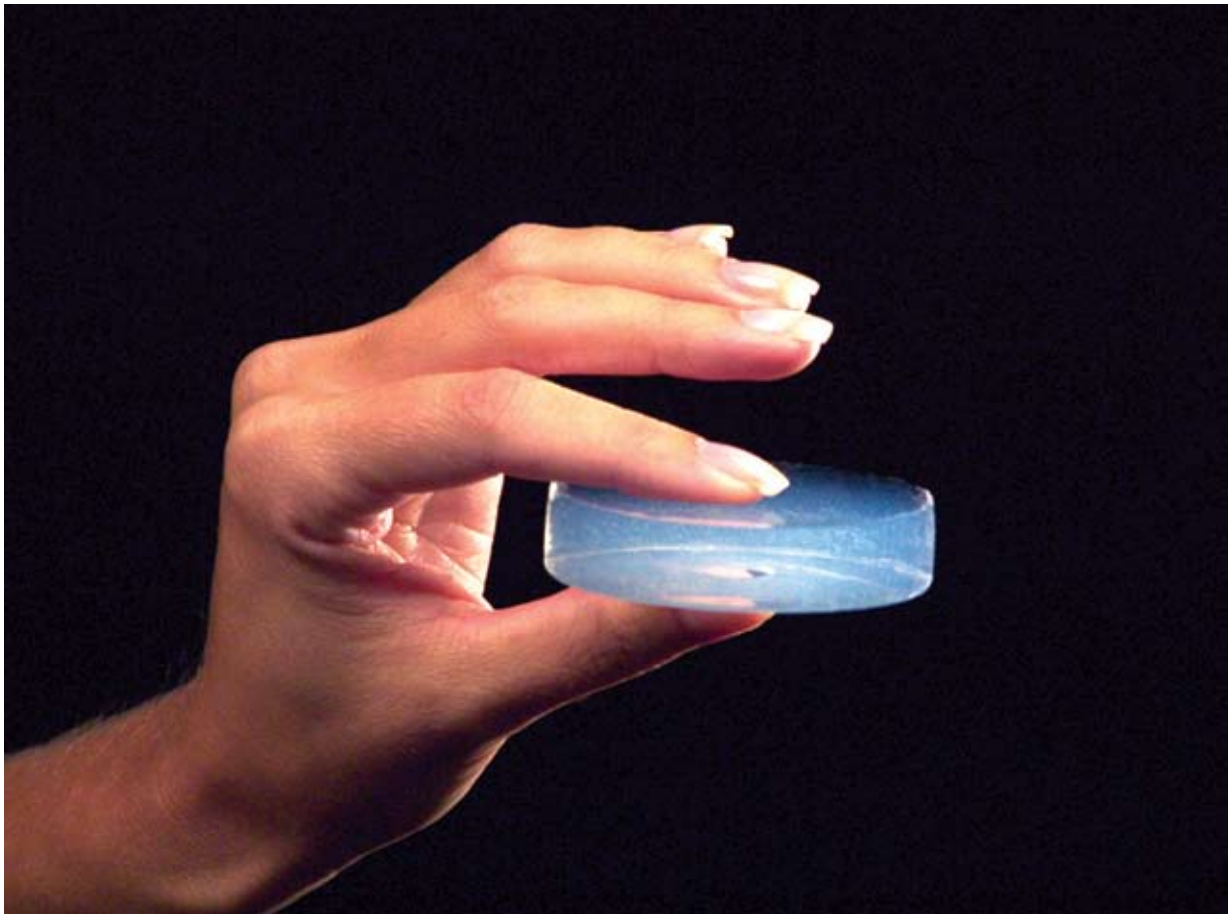
Aerogels Insulate Against Extreme Temperatures

Originating Technology/NASA Contribution

"When you hold a piece of silica aerogel, it feels otherworldly. If you drop it on a table top, it has an acoustic ring to it. It sounds like a crystal glass hitting the table," describes George Gould, the director of research and development at Aspen Aerogels Inc.

Similar in chemical structure to glass, aerogels have gas or air in their pores instead of liquid. Developed in the United States nearly 80 years ago by a man named Samuel Stephens Kistler, an aerogel is an open-celled material that is typically comprised of more than 95 percent air. With individual pores less than 1/10,000th the diameter of a human hair, or just a few nanometers, the nanoporous nature of aerogel is what gives it the lowest thermal conductivity of any known solid.

Crayons placed on top of a piece of silica aerogel will not melt from the heat of a flame. Certain types of aerogel provide 39 times more insulation than fiberglass.


Aerogel is made from a wet gel that is dried. The substance has been described as feeling like volcanic glass pumice; a very fine, dry sponge; and extremely lightweight Styrofoam.

The remarkable characteristics of silica aerogel—low density, light weight, and unmatched insulating capability—attracted NASA for cryogenic insulation for space shuttle and space exploration mission applications. For example, when a shuttle is fueled, it requires more than half a million gallons of cryogenic liquid oxygen and liquid hydrogen. To remain a liquid, hydrogen must stay at a cold -253 °C and liquid oxygen must remain at -183 °C. The systems necessary to deliver, store, and transfer these cryogenic liquids call for high-performance insulation technology at all steps along the way and into space.

Aspen Systems Inc. worked with NASA to manufacture a more durable form of aerogel. The flexible material is made by filling the spaces of a fiber web with silica aerogel.

In 1992, NASA started to pursue the development of a practical form of aerogel. Up until that point, aerogel had always been too fragile to handle in its monolithic (or solid) form, and too time-consuming and expensive to manufacture. The concept for a flexible aerogel material was introduced by James Fesmire, the senior principal investigator of the Cryogenics Test Laboratory at Kennedy Space Center. Fesmire, at that time a mechanical engineer responsible for cryogenic fueling systems design, envisioned an aerogel composite material that would be practical to use, but would still exploit the phenomenal heat-flow-stopping capability provided by the nanoporous aerogel.

Partnership

Kennedy Space Center awarded Aspen Systems Inc., a research and development firm in Marlborough, Massachusetts, a **Small Business Innovation Research (SBIR)** contract to create a flexible, durable, easy-to-use form of aerogel. The world's first aerogel composite blankets were produced in 1993 as cookie-sized laboratory specimens. Initial testing under cryogenic conditions showed the material to have exceptionally good insulating performance in ambient pressure environments. At that time, standard laboratory test machines were inadequate to fully characterize the material's very low heat transfer characteristics under cryogenic conditions. A second phase of the SBIR program, a collaborative effort with Kennedy, was awarded in 1994. As part of that collaboration, a cryostat insulation test apparatus was devised for measuring the true thermal performance of the aerogel blankets. This apparatus, Cryostat-1, was able to fully test the material and later became the cornerstone capability for the laboratory at Kennedy.

By 1999, these contracts led to further partnerships, and Aspen Systems developed a manufacturing process with NASA that cut production time and costs, as well as produced a new form of aerogel, a flexible aerogel blanket. To make the new material more useful, the spaces within a web of fiber reinforcement were completely filled with silica aerogel. "It's a little like an epoxy resin in the polymer composites world. By itself, epoxy resins can make great glue. But if you combine it with fiber, you can make airplanes and helicopters out of it," says Gould.

To develop and market the revolutionary product, Aspen Systems started Aspen Aerogels Inc. in Northborough, Massachusetts. Since 2001, Aspen Aerogels has been using the same manufacturing process developed in part under the NASA SBIR to provide aerogel to the commercial world. In 2003, Aspen Aerogels received the "R&D 100" award from *R&D Magazine*. By 2009, the company had become the leading provider of aerogel in the United States and currently produces nearly 20 million square feet of the material per year.

Aspen Aerogels Inc. produces nearly 20 million square feet of aerogel material per year and sells it for government, industry, and consumer applications.

Product Outcome

While NASA uses Aspen Aerogels' product for cryogenic applications such as launch vehicles, space shuttle applications, life support equipment, and rocket engine test stands, there is an array of commercial industrial applications including pipe insulation, building and construction, appliances and refrigeration equipment, trucks

A company called Polar Wrap LLC encapsulates the NASA-derived aerogel and uses it in a product called Toasty Feet (shown above and on the right). These insoles protect people's feet from both heat and cold.

and automobiles, as well as consumer applications, such as personal apparel. Most recently, the NASA-derived aerogel has been applied to protect and insulate people's hands and feet.

Polar Wrap LLC, is a Memphis, Tennessee, company that buys the material from Aspen Aerogels and then applies its own patented process to encapsulate the aerogel and use it in insoles called Toasty Feet. Designed to fit in the bottom of a boot or shoe, Toasty Feet resists heat loss and heat gain. According to the company, sales totaled over a million and a half pairs in 2009. Their line of insoles includes mens, womens, youth, extra cushion, and arch support.

The inventor of the process to encapsulate the aerogel for Polar Wrap was originally looking for insulation for the refrigeration system on his sailboat. When he saw the capabilities of aerogel, he thought the material held promise for the company. The inventor then devised an application for clothing, which resulted in the process now used to make Toasty Feet.

According to Polar Wrap, two people walked the length of the Great Wall of China (a 4,500-kilometer walk that took 6 months) wearing Toasty Feet. A mountaineer climbed Mount Everest using Toasty Feet instead of liner socks and said her feet stayed warm. In addition, an endurance runner who ran a marathon from Death Valley to Mt. Whitney, California, said her feet stayed heat-free while wearing Toasty Feet.

Another company looking for ways to warm feet—and hands—also decided to use Aspen Aerogels' product. Originals By Weber, of Toms River, New Jersey, is an Internet-based business. The owner, Terrance L. Weber, wanted a way to help people with Raynaud's disease, a condition that causes the fingers and toes to feel numb and cool in response to cold temperatures or stress. The smaller arteries that supply blood to the skin become narrow, limiting the blood circulation to affected areas.

Mountaineer Ann Parmenter summitted Mt. Everest on May 25, 2006. She said her feet stayed comfortable and warm while wearing just one pair of socks—plus Toasty Feet insoles—inside her climbing boots.

To keep the blood warm, Weber decided to try applying insulation to the wrists and ankles. After experimenting with several materials, including a fiberglass

The Wrist and Ankle Wraps (to the left and above) were made by Originals By Weber to help people with Raynaud's disease fight painfully cold hands, fingers, feet, and toes. According to the company, ultra-thin aerogel insulation assists in controlling and maintaining blood temperature, and also increases blood flow to the hands and feet.

product, he says, "I chose aerogel because it is thin and lightweight, and almost to the point where you don't even know it is there."

Encased in nylon, the Wrist and Ankle Wraps are secured with a strap to maintain the normal temperature of the blood as it flows from wrists to hands and fingers, and from ankles to feet and toes. In the course of 6 months, the company has sold about 75 pairs of the product.

In addition to insoles, and wrist and ankle wraps, the NASA-derived product has also made its way into boots. Salomon, a French company that sells sporting products, incorporates aerogel into its Toundra winter boots for men and women. Another French company, Heckel, incorporates aerogel insulation from Aspen Aerogels in its MACPOLAR boots. The company ensures comfort in temperatures as low as -50 °C, and promotes the boots for refrigerated warehouses, oil and gas exploration, snow and ski slope services, mines, transport services, and other harsh winter conditions.

Many new applications are on the horizon for space applications as well. The aerogel blanket material is enabling new ways of designing high-performance systems of all kinds for extreme environments. The atmospheres of Earth, the Moon, and Mars all present unique challenges for controlling and saving energy. With applications across various industries, Gould traces much of aerogel's commercial success to working with NASA early in the development cycle. "If you can meet NASA's high expectations for performance and safety requirements, and subsequently make a product that has commercial potential, you are on a great path to delivering goods that are the best in class." ❖

Toasty Feet™ is a trademark of Polar Wrap LLC.
Styrofoam™ is a trademark of The Dow Chemical Company.

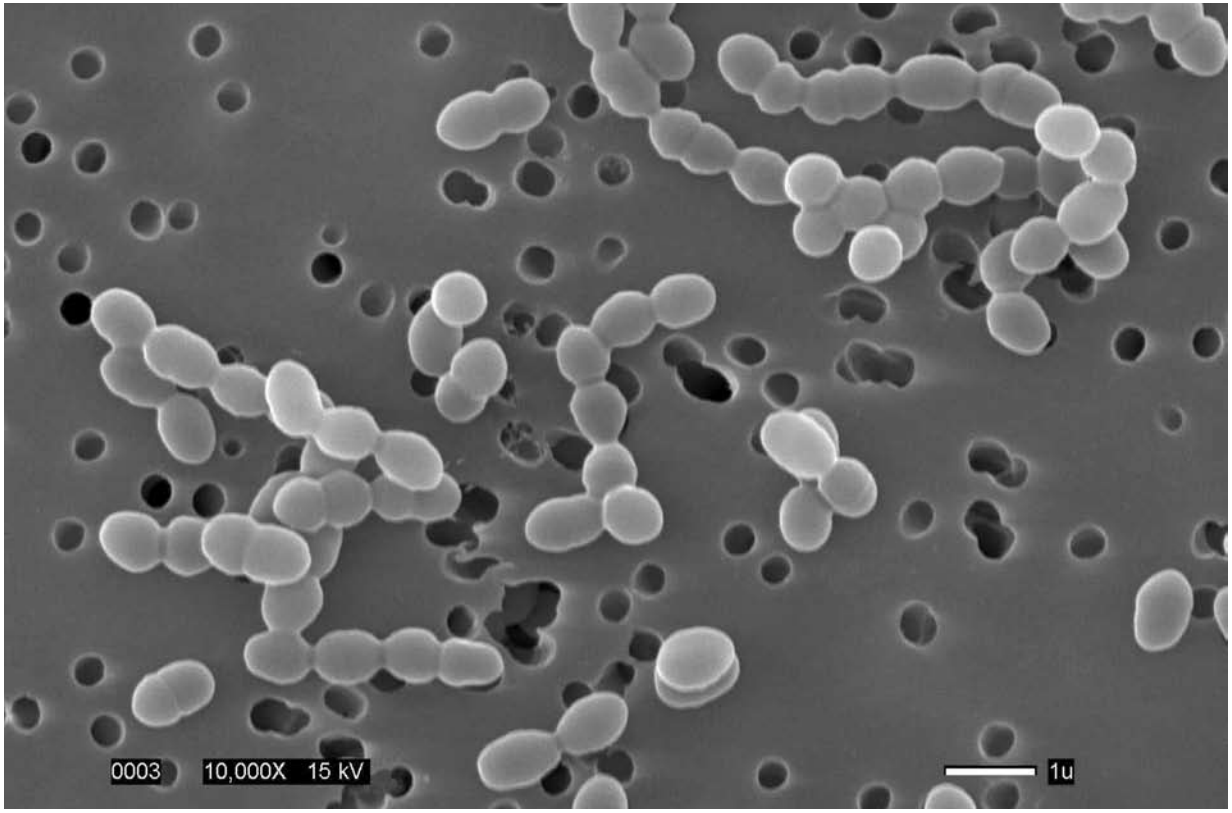
Bacteria Provide Cleanup of Oil Spills, Wastewater

Originating Technology/NASA Contribution

Given the size of our planet and its wealth of resources, it is easy to forget that those resources are finite. As Earth's human population continues to grow, the questions of how to effectively limit and recycle waste, avoid environmental contamination, and make the most of water and fuel reserves become all the more pressing.

On a much smaller scale, these same concerns apply to astronauts living within the closed system of the International Space Station (ISS). All resources onboard the ISS—air, water, energy—are limited and must be carefully managed and recycled to create a sustainable environment for the crewmembers. This challenge must be met without the natural systems that provide for and sustain life on Earth.

Well before construction of the ISS began in 1998, NASA was investigating ways water could be purified and reused by astronauts living in orbit. One method the Agency explored—through partnership with a small Texas company—involved bringing into space Earth's most abundant biological resource: bacteria.



Micro-Bac International Inc.'s microbial solutions, including formulations developed under NASA SBIR contracts, utilize specifically selected bacteria combinations to naturally break down organic compounds such as animal waste and oil, without yielding toxic byproducts.

Partnership

Micro-Bac International Inc., headquartered in Round Rock, began business in the early 1980s with the idea to selectively utilize Earth's natural waste management system to provide safe, efficient, and environmentally sound solutions for a host of applications.

"In the biosphere, everything gets broken down by microorganisms," says Dennis Schneider, vice president and director of research and development for Micro-Bac. "But in specific waste applications, you find that the right mix of microorganisms is not there. What we've found over the years is that we can isolate microorganisms out of the environment, and individual strains of those would have the capacity to break down certain types of organic compounds that are typically difficult to degrade." The bacteria accomplish this, Schneider explains, by producing protein enzymes that break down organic compounds into subunits, which the bacteria then grow on, creating more bacteria, carbon dioxide, and water.

"It's a natural process with no toxic byproducts," says Schneider.

Through Phase I and II **Small Business Innovation Research (SBIR)** contracts with Marshall Space Flight Center, the company developed a phototrophic cell for water purification. Inside the cell: millions of photosynthetic bacteria from strains specifically isolated for their ability to break down toxic chemicals astronauts could encounter on the ISS. Requiring only enough light to sustain the bacteria, the cell could provide a low-power option for cleansing wastewater during long-term space missions.

Micro-Bac proceeded to commercialize the bacterial formulation it developed for the SBIR project. MegaBacTF, first featured in *Spinoff* 1999, is among the microbial products the company offers to the benefit of cities and industry around the world.

Product Outcome

Mega-BacTF is now part of an expanded Mega-Bac product line formulated for organic materials degradation and odor control in large bodies of water like municipal lagoons. Mega-Bac products are also used for the remediation of animal waste, wastewater systems, and septic tanks, and are employed in waste treatment for livestock farms and food manufacturers. The leading U.S. pork producer, tortilla plants, juice makers, microbreweries, and even tequilerias in Mexico use Micro-Bac's natural, nonpathogenic biotechnology to help limit the environmental impact of their waste byproducts. The company's bacterial solutions are also popular in tropical regions such as Brazil, where plentiful sunlight makes Micro-Bac's photosynthetic bacteria a cost-effective alternative to the traditional sludge systems used in municipal wastewater treatment. Micro-Bac also offers products designed to treat hazardous and contaminated waste; dairy waste; grease, fats, and oils; waste from fruit and vegetable processing; and waste from leather tanning.

"We're into just about anything you can imagine that involves organic material degradation," Schneider says. The company has collected bacterial species from around the world and carefully formulates its products using specific strains that work in harmony to target each customer's environmental issue—no genetic engineering involved and no special handling measures or equipment required.

"Wood, for example, is slow to break down in nature," Schneider says. "But you can find microorganisms that can break down wood very quickly. You can target specific applications."

Micro-Bac offers more than specific waste treatment solutions. The company is also a leading provider of microbial products for improving oil production. Oil wells often struggle with the accumulation of compounds like paraffins and asphaltenes, components of crude oil that can settle out and create deposits that can bring oil production to a standstill and require costly maintenance treatments to remove. Micro-Bac's oilfield products, which include strains of bacteria from the company's NASA-derived formulation, break down those deposits, leading to significant boosts in productivity—one Kansas oil well increased its production over 500 percent after treatment with Micro-Bac products.

Micro-Bac's products have been used for oil spill cleanup, such as at this site in the Amazon rainforest in Ecuador, and is being employed in mitigating the environmental damage caused by the 2010 oil rig explosion and spill in the Gulf of Mexico.

These same qualities make Micro-Bac's oil-targeted products effective tools for countering environmentally damaging oil spills. The company has assisted in the cleanup of crude oil spills in Ecuador, and officials called upon Micro-Bac's microbial solutions to help mitigate the environmental impact of the catastrophic 2010 oil rig explosion off the coast of Louisiana by breaking down oil that reached shore.

Micro-Bac continues to develop targeted biotechnology for its customers' waste treatment and oil production applications, including a granulated version of its liquid crude oil degrading products. Customers will be able to keep the dried product on hand to simply sprinkle on any small oil spills. Meanwhile, the derivatives of the company's small-scale NASA collaboration continue to help address large-scale environmental and energy concerns in the United States and beyond.

"A wellspring of utility has come out of that work," says Schneider. ❖

LED Systems Target Plant Growth

Originating Technology/NASA Contribution

Living in space long term will require a sustainable environment. Plants provide fresh food, clean air, and clean water that will assist this effort, but plants need light to grow, and light requires energy. Here on Earth, most plants get this light from the obvious abundant source, the Sun. The Sun's solar radiation is ideal for growing plants here on Earth, but it presents some problems for plant growth in space. For starters, the lengths of the days are different depending upon the location of the garden. For growing plants on spacecraft, this problem is compounded, as the vehicle position is constantly changing and is usually not positioned for optimal plant growth. Thus, NASA has been developing methods for growing crops in space using artificial light sources.

Lighting plants with electric lamps overcomes several difficulties, but presents an additional problem: It can require a great deal of valuable energy and produce unwanted heating of the plants. The solution appears to be LED lighting, which allows for precision and control, uses less power than traditional lamps, and radiates minimal heat onto the plants. In addition, LED lighting typically lasts much longer than traditional bulbs, is smaller and lighter weight, and does not present the same potential risks of glass breakage as traditional bulbs.

The NASA-derived light distribution systems are low power, relatively cool, uniformly irradiate all leaves with wavelengths most efficiently absorbed by photosynthetic tissue, and automatically adjust emissions to target new tissues as plants grow in height or spread, without wasting photons by lighting empty space.

Partnership

To help develop technologies for growing edible biomass (food crops) in space, NASA partnered with a small business in Wisconsin. Orbital Technologies Corporation (ORBITEC), located in Madison, is one of the state's leading developers of new and cutting-edge aerospace technologies. The company has been awarded over $125 million in government contract funds over the course of more than 180 contracts, most of which were through commercial contracts that began in the **Small Business Innovation Research (SBIR)** program. Over the course of its extensive government work, ORBITEC was awarded Wisconsin's "Professional Service Business of the Year" in 1995 and received the "Tibbets Award" both in 1996 and 1999 from the Small Business Administration. The "Tibbets Award" acknowledges small businesses that have performed exceptionally well within the SBIR program. One of the highlights of ORBITEC's space-related work includes the 2002 launch of its Biomass Production System aboard STS-110 for a 73-day stay aboard the International Space Station.

One of the recent projects ORBITEC has been working on with Kennedy Space Center is the development of the High Efficiency Lighting with Integrated Adaptive Control (HELIAC) system, which uses targeted solid-state LEDs to efficiently grow plants. One configuration of the HELIAC system consists of a series of LED light panels called light engines. About 4 cm square and arranged in rows called "lightsicles," these light engines are precision-controlled and allow for maximum efficiency in plant growth. Research for space applications is continuing through a partnership between ORBITEC and Purdue University.

While NASA is keen on this promising technology for future experiments in space, hardware and software protocols developed through the HELIAC program have the potential to save energy in commercial agriculture and in aquarium lighting while providing a host of additional benefits.

Product Outcome

LED lighting systems are robust, easy to maintain, require less energy, produce little radiant heat, and reduce the dangers associated with pressurized bulbs, broken glass, mercury and high surface temperatures. What makes them truly ideal for plant growth, though, is their variable light output control. ORBITEC's precision HELIAC control system allows lamp configuration to be adapted to a specific plant species during a specific growth stage, allowing maximum efficiency in light absorption by all available photosynthetic tissues. It can sense the presence of plant tissue and only power the adjacent elements, thus providing efficient, targeted lighting. Picture, for example, a newly sprouted plant. Traditional lighting for this plant would be broad and scattered mostly over the growing medium. The HELIAC system is able to sense exactly where the plant's leaves and shoots are and spotlight those areas. This significantly reduces energy usage.

So far, ORBITEC has implemented a number of the technologies developed under the HELIAC project—several advanced control algorithms, sensors, drive circuits, thermal systems—into its commercial products. For example, horizontal light bars that allow real sunlight between the bars when available have been sold to research universities and controlled environment system manufacturers. The supplemental lighting allows growers to take full advantage of natural sunlight while also providing targeted lighting if sunlight is not available. This allows, for example, the plants to continue getting necessary light even on cloudy or rainy days.

The University of California, Davis purchased 216 of ORBITEC's greenhouse bars for photobiology research, while many other customers are purchasing these units on a smaller scale for research or evaluation of the new technology for full-scale implementation. The units are still manufactured in-house by ORBITEC, but this may change as demand increases. Currently, though, the technology is constantly evolving.

Another application ORBITEC has found for its controllable plant growth technology is in aquarium lighting. In aquariums, water temperature is a major issue—it has to be just right for certain fish or corals to thrive. With a traditional light fixture, an aquarium also needs to be equipped with a chiller to keep the water from heating. With LEDs, which produce minimal radiant heat towards the water, this is not a problem. They also last much longer than traditional bulbs.

The primary advantage of the ORBITEC system over other LED-based aquarium lighting systems, however, is the programmability. Using drive circuitry, software, and thermal protocols developed for the NASA work, these lights offer unprecedented adaptability and precise controls. They can be set to provide a specific spectrum depending upon the contents of the aquarium. Subtle spectral adjustments can be made for coral or specific fish. The lights can even be set, for example, to dim periodically to create the illusion of a cloud passing over head, the changes of the tide, or to simulate the lunar cycle. These sophisticated settings allow aquarium life to grow and thrive as if it were in a natural environment.

Currently, ORBITEC has licensed this technology to two aquarium lighting manufacturers, one of which, C2 Technologies Inc., is manufacturing the devices and marketing under the name AquaIllumination. ❖

AquaIllumination™ is a trademark of C2 Technologies Inc.

These LED systems substantially lower energy costs of controlled-environment production and will improve profitability.

Rocket-Powered Parachutes Rescue Entire Planes

Originating Technology/NASA Contribution

When Boris Popov was 8 years old, he took one of his mother's sheets and some thread, made a parachute, climbed a tree, and jumped. The homemade chute did little to break Popov's fall; his father took the disappointed boy aside and said, "Son, you've got to start higher."

Years later in the mid-1970s, recent college graduate Popov was hang gliding over a lake when the boat that was towing him accelerated too quickly, ripping the control bar from his hands. Some 500 feet in the air, Popov's glider went into a spiral, coming apart as Popov plummeted to the water. As he fell, Popov realized that if he only had some kind of parachute, he could have been saved. Before impact, he promised himself that, if he survived, he would create a solution that would save people in these types of emergency situations.

Decades later, the U.S. air transportation system was suffering its own kind of free fall. The terrorist attacks of 9/11 led to stringent security measures that complicated and slowed down air travel. Even as the industry recovered from the effects of the attacks, increased flights and passenger demand strained the National Airspace System (NAS) at levels never before experienced. At the same time, NASA was exploring ways of extending aviation to rural America using smaller general aviation (GA) aircraft and local community airports. The NASA Small Aircraft Transportation System (SATS) project envisioned an on-demand, point-to-point, widely distributed transportation system relying on small aircraft (4-10 passengers) operating out of the Nation's more than 5,400 public-use landing facilities. With about 98 percent of the population living within 20 miles of at least one such airport, SATS could provide cheaper, faster, and more practical options for business and leisure travel, medical services, and package delivery.

> ***"BRS is a classic example of taxpayers' money being spent on research that has translated into 246 lives saved."***

Though the SATS project concluded its research in 2006, the pursuit of a nationwide GA transportation system continues through other initiatives like NASA's Green Flight Centennial Challenge, scheduled for 2011, which encourages competing teams to maximize fuel efficiency for personal aircraft, as well as reduce noise and improve safety. Technological advances are still necessary, however, to make such a system viable, such as improving the safety of small aircraft. One solution has come in the form of an invention developed by Popov, who having survived his fall, began investigating methods of ballistically deploying parachutes for aircraft in emergency situations. Today, with the help of a NASA partnership, the parachute that Popov wished for when plunging to Earth is saving hundreds of small aircraft pilots from a similar fate.

Partnership

Popov founded Ballistic Recovery Systems Inc. (now BRS Aerospace) of Saint Paul, Minnesota, in 1980. He formed the company to commercialize his solution to personal aircraft accidents like the one he experienced: a whole aircraft parachute recovery system. Soon BRS was developing parachutes for hang gliders, ultralights, and experimental aircraft, and the company received Federal Aviation Administration certification for a retrofit system for the Cessna 150 GA airplane. The company's innovative safety solution for small aircraft led to **Small Business Innovation Research (SBIR)** contracts with Langley Research Center aimed at advancing the BRS parachute system for use with larger and heavier GA aircraft. The NASA funding helped BRS with the development of thin-film parachutes, continuous reinforcement manufacturing methods that result in stronger parachutes, and smart deployment devices—all of which help overcome one of the main obstacles to whole-aircraft parachute systems for larger vehicles: reducing bulk and weight while maintaining parachute strength.

"You can't have a 50-gallon drum full of parachute in the back of a Cessna. It's not going to work," Popov says. Just as important as the research and development funding for BRS, he says, was NASA's support of its parachute system.

"One of our primary needs for working with NASA was to promote and encourage the concept of a ballistic parachute on aircraft," Popov says. "There was a lot of skepticism that this system could even work. NASA was very proactive in creating a safety mentality in general aviation."

This BRS Aerospace Inc. parachute system, designed for sport aircraft, deploys its chute (contained in the white canister) in less than 1 second, thanks to a solid rocket motor (the black tube on top).

With the help of NASA funding, BRS developed parachutes that have saved hundreds of small aircraft—and their pilots and passengers. Here, a Cirrus SR20's parachute deploys at over 100 miles per hour, arresting the plane's descent. BRS parachute systems are standard equipment on Cirrus aircraft.

Product Outcome

The BRS parachute system—first featured in *Spinoff* 2002—is deployed by a solid rocket motor activated when the pilot pulls on the cockpit handle release. The rocket fires at over 100 miles per hour and extracts the parachute in less than 1 second. Thanks to a patented shock attenuation device, the chute opens according to the speed of the aircraft; at high speeds, the chute opens only 25 percent for the first few seconds to reduce airspeed to the point where the chute can open fully and still sustain the opening shock. (The lightweight parachute material has to sustain the force of the rocket deployment, as well as the force of the aircraft.) At low speeds and altitudes, the chute opens quickly and completely to ensure rescue.

The system's versatility makes it effective in a range of accident situations, from mid-air collisions and structural failure to a spiral dive or stall spin. The parachute arrests the descent of the entire aircraft and deposits the vehicle and its occupants on the ground with a typical impact force equivalent to falling 7 feet, which is largely absorbed by the aircraft's landing gear and seats. Not only are lives saved, but in many incidents, expensive aircraft are preserved to fly again.

BRS has sold more than 30,000 systems worldwide since its founding. The parachute is now standard equipment on the Cirrus SR20 and SR22 planes, the Flight Design CT light-sport aircraft (LSA), the Piper Aircraft PiperSport LSA, and as an option on the new Cessna 162 Skycatcher. The company is projecting sales of close to $20 million this year.

"Our system is standard equipment on the world's top selling single-engine aircraft, Cirrus. It's standard equipment on the world's top selling LSA, the CT. The number one producer of ultralights has our product as standard equipment. You can see a trend here," Popov says.

BRS also produces parachute systems for military unmanned aerial vehicles, military cargo parachutes, and military training aircraft recovery parachutes. On training aircraft, if the pilot has to eject, "you basically have a 5,000-pound bomb that could go unpiloted down into a neighborhood," Popov says. "We, however, can bring down the pilot and trainer aircraft safely to the ground."

While parachutes for larger aircraft are still in the works, BRS does have a system designed for small jets, and its NASA partnership has provided the company with the technology that may eventually enable parachutes for commercial airlines and jets. In the meantime, Popov welcomes the role NASA has played in helping turn the promise he made to himself that day at the lake into a reality for the 246 people whose lives have been saved by the BRS parachute so far.

"BRS is a classic example of taxpayers' money being spent on research that has translated into 246 lives saved," he says. "That's a justifiable and profound benefit."

He tells a favorite story about a grandfather flying a Cirrus SR20 over the Canadian Rockies with his grandkids in the back seat. The grandfather lost control of the plane, which became inverted at night in the mountains. "You're likely not going to recover from that," Popov says. The grandfather deployed the parachute, and the plane settled gently on the side of mountain, where a rescue helicopter found it the next day. After being hoisted out by a helicopter and flown to a nearby airstrip, they put on a new prop and landing gear and flew the plane out.

"This grandfather thought he may have just killed himself and his grandkids, but when he pulled the handle and felt the parachute deploy, he knew he had just prevented that from happening," Popov says.

"How many millions of dollars is that worth?" ❖

Technologies Advance UAVs for Science, Military

Originating Technology/NASA Contribution

Greek mythology tells of the inventor Daedalus using wings of his own fashioning to escape from imprisonment on the island of Crete. In 1988, a similar adventure was launched, though in this case carbon-fiber composites, gears, and driveshafts featured instead of wax and feathers.

A year earlier, a group of students, alumni, and professors from the Massachusetts Institute of Technology (MIT) gathered at Dryden Flight Research Center to begin a series of test flights for what they hoped would be a record-setting effort. Inspired by the Greek myth, the team built and tested three lightweight, human-powered aircraft designed to reenact Daedalus' (according to the tale) 115-kilometer flight. After numerous test flights of the three aircraft (and one crash), the 69-pound Daedalus 88 launched from Crete in April 1988. Powered only by the pedaling of the pilot, a Greek champion cyclist, the aircraft flew nearly 4 hours and 199 kilometers before winds drove it into the sea just off the coast of the island of Santorini. (If this calls to mind the demise of Daedalus' son Icarus, do not worry; the pilot swam to shore.)

The Daedalus 88 aircraft is seen here on its last flight at Dryden Flight Research Center in 1988. The aircraft set records for human-powered flight that still hold today.

Setting distance and duration records for human-powered flight that are still unmatched today, the Daedalus project provided NASA and the MIT team the opportunity to explore new technologies for lightweight aircraft and high-altitude, long-duration flight. Also from this effort came the kernel of a company that—with the help of NASA partnerships—is producing some of the world's most advanced aviation technologies.

Partnership

In 1989, John Langford founded Aurora Flight Sciences Corporation in a small office in Alexandria, Virginia. Langford had managed the Daedalus project and saw great potential in applying the technologies developed for that effort to the innovation of high-altitude unmanned aerial vehicles (UAVs) for global climate change research. Almost immediately, Aurora established a pattern of partnership with NASA that continues today.

"NASA has been a critical supporter of Aurora from day one," says Langford. The company has engaged in numerous **Small Business Innovation Research (SBIR)** and **Small Business Technology Transfer (STTR)** projects with the Agency, beginning with its initial Ames Research Center SBIR, for the development of a fuel cell-based high-altitude propulsion system, up until its most recent contract in 2009 to create aspirated compressors for a high-altitude, long-endurance (HALE) concept engine for Glenn Research Center. These partnerships have provided opportunities for Aurora on multiple fronts, Langford says.

"There is a technology development function, a personnel development function, and also a collaboration function through SBIRs and STTRs," he explains. "We have bright new talent, and these programs provide a great way for people to explore new ideas."

Aurora, now headquartered in Manassas, Virginia, has also worked with NASA on several unique initiatives. The company developed the Perseus A, Perseus B, and Theseus test bed UAVs for NASA's Environmental Research Aircraft and Sensor Technology (ERAST) program. Designed to encourage the advancement of cost-effective UAVs for HALE science missions, ERAST was instrumental in the creation of new UAV technologies like the Predator B, known as the Altair in its NASA science mission version and as the MQ-9 Reaper for the military. Aurora also designed and created a series of UAVs for potential long-range science missions on Mars.

In addition, a Space Act Agreement with Goddard Space Flight Center and West Virginia University was significant to Aurora's commercial activities today. Through the partnership, Aurora developed low-cost composite materials manufacturing capabilities and opened a manufacturing facility in West Virginia. These outcomes enabled Aurora to provide cost-efficient airframe parts for the Teledyne Ryan (now Northrop Grumman) Global Hawk UAV, designed for the U.S. Air Force.

Product Outcome

Aurora now has 350 employees and has facilities in Mississippi and Massachusetts, in addition to its West Virginia and Virginia operations. The company employs 160 people in its NASA-enabled West Virginia plant, and about one-third of Aurora's work force is dedicated to the company's Global Hawk efforts. Aurora now supplies all the composite structures for Global Hawk, save for the wings.

"This is an example of economic development done right," Langford says. "You want to build up the economy

Through a Space Act Agreement, Aurora Flight Sciences Corporation developed manufacturing techniques that enable the company to provide much of the composite airframe for the Global Hawk UAV (left). These capabilities allowed Aurora to open a manufacturing facility in West Virginia that now employs 160 workers. The company also develops its own cutting-edge UAV designs, such as the GoldenEye 80 ducted-fan aircraft (right) for military surveillance applications.

across the country, and this was a move that NASA participated in that has been very successful."

The partnership has also allowed Aurora to contribute to the use of UAVs for scientific endeavors; NASA's two Global Hawk aircraft began long-duration science missions over the Pacific Ocean in 2010 as part of the Agency's Global Hawk Pacific Mission.

"We are very proud of the fact that parts of those planes were built in our West Virginia facility," Langford says.

Aurora's expertise in advanced aviation development—cultivated in part through its NASA work—has led to the creation of unique robotic aircraft that are providing entirely new takes on UAV design and function. Aurora's GoldenEye and Excalibur aircraft are both vertical takeoff and landing vehicles with science-fiction looks. The GoldenEye 50 and the larger GoldenEye 80 are ducted-fan aircraft designed to provide highly portable surveillance for military applications. Excalibur is an armed tactical UAV that takes off on one side and then rolls over for mission mode, protecting its sensors from any dust kicked up by its propulsion system.

"A lot of aircraft missions are not involved with carrying people, and when you take the people out of the equation, it completely changes the design space," explains Langford. "GoldenEye and Excalibur are examples of designs that have no analog in manned aircraft."

The popularity of UAVs has risen dramatically in recent years, Langford says. "Ten years ago, all the UAVs in the world flew a few thousand flight hours per year, total. This last year, UAVs flew between 500,000 and a million flight hours." Such growth is remarkable, he says, but still hardly compares to the 100 million manned flight hours flown each year worldwide. And science missions are still a vast minority of UAV applications, though Langford predicts that will change with NASA's help.

"Understanding and protecting our planet is a huge reason why taxpayers should be enthusiastic about NASA."

"We are extremely excited about the renewed emphasis on aeronautics and global change research. It is something only NASA can do, and it fits perfectly with NASA's heritage, mission, and capabilities. Understanding and protecting our planet is a huge reason why taxpayers should be enthusiastic about NASA."

In the meantime, Aurora is continuing work on a number of UAV projects, including its Orion HALL (high-altitude, long-loiter) aircraft, which can fly for 5 days nonstop, and the Centaur optionally piloted airplane. And while the original Daedalus aircraft that inspired Aurora's founding set records with its nearly 4-hour flight, the company is also working on a project that may one day perform flights of positively mythical proportions: The solar-powered Odysseus aircraft may one day be capable of flying for up to 5 years at a time. ❖

Toolsets Maintain Health of Complex Systems

Originating Technology/NASA Contribution

Monitoring the health of a machine can be just as tricky as monitoring the health of a human. Like in the human body, a variety of subsystems must work together for a machine to function properly—and a problem in one area can affect the well-being of another. For example, high blood pressure can weaken the arteries throughout the body, and weakened arteries can lead to a stroke or kidney damage. Just as a physician may prescribe medication, a special diet, or a certain exercise routine to maintain the health of a person, NASA employs a systems health management approach to ensure the successful operation of its rockets, crew vehicles, and other complex systems.

As a unique engineering discipline, systems health management prevents and minimizes problems in systems by using processes, techniques, and technology to design, analyze, build, and operate the systems. The goal is to understand a system, accurately assess its health (how well it is working), pinpoint any problems, and then support any maintenance or repair activities. Such an approach is critical to the success of NASA missions.

Partnership

To strengthen the systems health management approach used for NASA's large, complex, and interconnected systems, Ames Research Center awarded Qualtech Systems Inc. (QSI), of Wethersfield, Connecticut, several **Small Business Innovation Research (SBIR)** contracts. As a result, QSI adapted its Testability, Engineering, and Maintenance System (TEAMS) toolset and then employed the technology for the detection and isolation of electromechanical problems on the International Space Station (ISS) and again for the thrust vector control subsystem and ground hydraulics for the Ares I-X test flight in 2009.

First featured in *Spinoff* 2001, today the toolset includes TEAMS-Designer, a program that creates a model of the system and performs a large portion of the analysis; TEAMS-RT, a software embedded in the system for real-time monitoring and diagnosis; TEAMATE, software that communicates step-by-step guidance on how to troubleshoot a problem; and TEAMS-RDS, an enterprise-level server that enables maintenance and troubleshooting from a Web-based server, as well as a collection of field failure information for further improvement of troubleshooting strategy and to enhance future designs. Together, the toolset captures knowledge about how a system fails, how the failures are detected, and then uses that knowledge to guide engineers in troubleshooting and making real-time diagnoses.

The TEAMS toolset was employed on the Ares I-X test vehicle, shown here at Kennedy Space Center's vehicle assembly building. TEAMS is also applicable to transportation systems, medical equipment, factory systems, telecommunications, and refinery systems.

Over the past decade, QSI has received significant funding through SBIR awards with NASA and the U.S. Department of Defense, and has advanced system diagnosis and health management, two of QSI's core capabilities. In 2002 and 2008, QSI received Space Act Awards from NASA, and in 2002, the *Aviation Week* award in recognition of the capabilities and advancements in TEAMS software. Now, Ames, Johnson Space Center, Kennedy Space Center, Glenn Research Center, Marshall Space Flight Center, and Jet Propulsion Laboratory all utilize TEAMS in support of NASA's Exploration Systems Mission Directorate.

Product Outcome

QSI has also adapted TEAMS for the business and technical requirements of large-scale commercial operations. After transitioning from a provider of consulting and engineering services to a provider of software products, QSI experienced revenue growth of more than 50 percent in less than 2 years, and also expanded its presence from the United States to Japan, Israel, and China.

Originally tailored for complex research applications at NASA, TEAMS can function in much the same way for simpler applications. Whether a system propels a spacecraft or an automobile, generates power, carries data, refines chemicals, performs medical functions, or produces semiconductor wafers, the conditions that cause the equipment to fail can be modeled and analyzed, then linked to test procedures, and finally generate a troubleshooting solution.

Dr. Somnath Deb, president of QSI, explains that a failure in one subsystem can propagate to other subsystems and generate false indications. "The subsystems are usually designed by different groups of people who don't

know too much about each other's subsystems. TEAMS connects the dots and provides a comprehensive and accurate picture of the health of the entire system."

According to QSI data, TEAMS can substantially lower costs by decreasing warranty costs for manufacturers by 15 to 30 percent; diagnostic time across industries by 40 to 80 percent; calls to a call center by 30 to 60 percent; on-the-job training time by 30 to 60 percent; problems requiring field service by 30 to 50 percent; and repeat service calls by 70 to 90 percent.

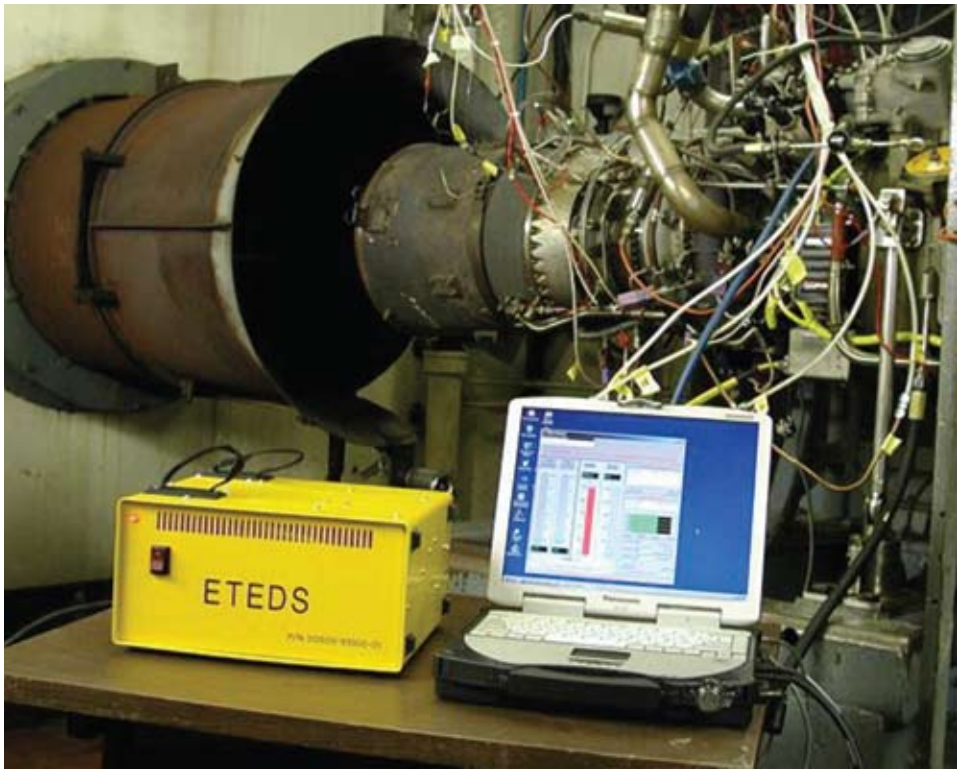
In addition, QSI reports that one high tech company in the United States started utilizing TEAMS after comparing the time it took trained experts versus newly trained students to troubleshoot a mechanical issue. The student took 8 hours; the expert took 7.5 hours; using TEAMS, it took half an hour to troubleshoot the issue. According to QSI, field service engineers perform equally well when using TEAMS because it provides step-by-step instructions for troubleshooting.

A number of companies, including KLA-Tencor, Orbotech, Honeywell, General Motors (GM), Sikorsky, BAE, and Lockheed Martin are benefiting from using the NASA-derived technology for innovative new projects.

KLA-Tencor, a large semiconductor equipment manufacturer, is using the TEAMS tools for diagnosing and troubleshooting its suite of equipment at semiconductor fabrication sites around the world. The company expects a quick return on investment from its worldwide deployment of the TEAMS technology.

Orbotech, a supplier of inspection systems for printed circuit board production, deployed TEAMS in seven countries on three continents for its field service workforce. In this application, TEAMS averaged 75-percent accuracy on troubleshooting for new products without a maintenance history.

Under a subcontract for NASA, Honeywell selected TEAMS-RT for onboard vehicle health determination. Honeywell performed an evaluation of the competing technologies and selected TEAMS-RT for real-time diagnosis of the space flight vehicle Orion. Previously, Honeywell used TEAMS-RDS to monitor ISS data at Johnson, provide early detection and mitigation of problems, and supply continuous awareness of ISS health.



According to Qualtech Systems Inc., TEAMS software can lower service costs by decreasing problems requiring field service by 30 to 50 percent. Shown here with accompanying test equipment called the enhanced turbine engine diagnostic system, TEAMS software is used on a laptop to model the T-700 helicopter engine in a test environment.

GM is also using TEAMS to evaluate how TEAMS-RDS could be used with its OnStar system, an in-vehicle security, communications, and diagnostics system. GM hopes to enable OnStar to read car engine codes and then tell the technician which part to repair. Deb explains, "This makes car maintenance more proactive because engine codes often show up before the car stalls or dies. Proactive maintenance would ensure the car drives well and the end user is not inconvenienced. Other companies are looking at TEAMS from this angle too."

Fine-tuning its product with NASA has been extremely beneficial for QSI. "NASA wants the best, so it is open-minded and not only looks for the best, but also to bring out the best in you," says Deb. "NASA points out what to improve and how, and the SBIRs are a great vehicle for a small business to make improvements in a technology and still obtain ownership of it. That made a huge difference in making us who we are." ❖

Terahertz Tools Advance Imaging for Security, Industry

Originating Technology/NASA Contribution

On January 16, 2003, the Space Shuttle Columbia launched on mission STS-107. At T plus 82 seconds, with the orbiter rocketing upwards at 1,870 miles per hour, a briefcase-sized chunk of insulating foam broke off from the external fuel tank and struck Columbia's left wing. During reentry on February 1, hot gasses entered the wing through the damaged area of the orbiter's thermal protection system, causing devastating structural failure that led to the destruction of Columbia and the deaths of the seven crew members onboard.

After the Columbia disaster, NASA grounded the space shuttles for more than a year as it worked on new safety protocols to ensure that such a tragedy would not happen again. As part of the preparations for the Return to Flight mission, the Agency required a method for detecting potentially hazardous defects in the external tank's sprayed-on insulating foam prior to launch.

Partnership

NASA Langley Research Center scientists suspected that a new imaging technology called terahertz imaging had the potential to accurately find flaws in the foam on the external tank. Terahertz radiation—lying between microwaves and far infrared on the electromagnetic spectrum—offers imaging capabilities similar to X-rays, but unlike X-rays, terahertz radiation is non-ionizing and thus safe for frequent human use. Terahertz wavelengths can be used to see through many materials and reveal defects like cracks, voids, and density variations. They can be used to image or as an anomaly detector, or both at the same time.

Picometrix, of Ann Arbor, Michigan, was at the forefront of the emerging field of terahertz imaging. In 2000, Picometrix introduced the world's first commercial terahertz system, the T-Ray 2000. The T-Ray 2000 was based upon the company's patented fiber coupling system, but was a non-integrated, workbench-mounted system, which rendered it fine for the research market but impractical for NASA's manufacturing quality control needs. Langley researchers asked the company via **Small Business Innovation Research (SBIR)** agreements to quickly redesign the terahertz systems to be more integrated and deployable into a manufacturing environment.

The space shuttle's external tank is coated in insulating foam that must be checked for defects. To accomplish this, NASA turned to the developing field of terahertz imaging.

Terahertz can be employed as a safer, more precise security measure than X-rays.

Based on the success of that new prototype system, the company was next asked to deliver a more compact, self-contained terahertz system, the T-Ray QA-1000, and NASA purchased five of the systems for inspecting the external fuel tanks as they were being manufactured by Lockheed Martin. The QA-1000's long, optical fiber umbilicals enabled the system's terahertz sensors to scan the tank from top to bottom. The systems were deployed at NASA's Michoud Assembly Facility and at Marshall Space Flight Center. Langley's original unit was later retrofitted with a similar higher speed delay stage that was also capable of imaging thicker foam.

"This was significant. In addition to the company's patented fiber coupling system that makes Picometrix systems unique, they can also inspect thicker material at substantially higher speed with our T-Ray systems versus others terahertz systems," says Irl Duling III, company director of terahertz business development.

Picometrix became a wholly owned subsidiary of Advanced Photonix Inc. (API), also of Ann Arbor, Michigan, in 2005. The company's terahertz systems—including its latest, highly compact and rugged T-Ray 4000 systems—were later adopted by Kennedy Space Center as a diagnostic tool for scanning the orbiter's thermal tiles for the remaining shuttle flights. The systems offered an effective way of not only inspecting the tiles for hidden damage, but also of precisely locating components underneath the tiles that were in need of attention—

without the costly removal and replacement of extra tiles which often happened before the use of the T-Ray 4000.

"With this technology, NASA could scan and see the precise location of wires and antennas and remove only the necessary tiles," says Picometrix engineer Greg Stuk. "In one example, it saved the Agency hundreds of thousands of dollars."

Product Outcome

The imaging capabilities of terahertz make it useful for a wide range of applications. It can be employed as a safer, more precise security measure than X-rays in airports and other buildings, revealing concealed weapons and the contents of packages. Since numerous materials have specific spectral signatures revealed by terahertz radiation, it provides spectroscopic and other unique identification information useful for chemical analysis, pharmaceuticals, and explosives detection. Not only can terahertz see through an opaque pill bottle, for example, it can also reveal the chemical makeup of the pills inside. It can also provide high-resolution imaging down to 200 microns. The industrial possibilities of terahertz range from determining the uniformity of coating thickness to detecting hidden defects to ensure product quality.

The company now offers the T-Ray 4000 Time-Domain Terahertz System commercially. Featuring its patented fiber-pigtailed transmitter and receiver modules, the T-Ray 4000 is designed for both the research laboratory and the industrial setting. The T-Ray 4000 takes the next step beyond the NASA-inspired T-Ray QA-1000 system. While the QA-1000 is about the size of a small refrigerator, the T-Ray 4000 is an easily portable, rugged, briefcase-size system weighing only about 50 pounds. As a time-domain terahertz system, the T-Ray 4000 generates high-speed picosecond (one-trillionth of a second) duration terahertz pulses for scanned spectroscopy or imaging. These qualities, along with the patented fiber-coupled sensor heads that can scan objects of almost any size, make the T-Ray 4000 an easy-to-use tool for terahertz applications beyond the laboratory—though it is useful there as well.

The T-Ray 4000 Time-Domain Terahertz System, capable of generating high-speed terahertz pulses and equipped with fiber-coupled sensor heads, is a versatile and user-friendly instrument for use in the laboratory and in real-world applications.

"As far as having a product that you can deploy onto a manufacturing floor, this is the first of its kind," says Duling. He credits the company's NASA work with helping drive this industry-leading advancement.

"The rest of the industry is trying to figure out how to generate terahertz, how to detect it, how to build a complete system that can be fielded," he says. "In part through NASA's motivation, we've been able to complete that full-system integration and turn it into something we can take out into the field and use as a tool."

"Our systems' features now allow terahertz to access the most obscure places," says Steve Williamson, the company's chief technology officer. "It's a powerful benefit to our customers."

API's terahertz systems can be used for thickness measurements of roofing material, paper and paper coatings, and coatings on films. They also can be employed for pharmaceutical applications like aseptic packaging and tablet production. Art conservationists from prestigious institutions like the Uffizi Gallery and the Louvre have used API systems to date paintings, look for pigment concentrations, and reveal frescos on walls that have been painted over. The technology has been even applied to examine the structure of pagodas in Japan, providing guidance for renovations. These are only a few examples of the benefits of this still developing field, says API CEO Richard Kurtz.

"Terahertz has huge market potential. We estimate there are over $200 million in opportunities for our terahertz systems over the next 7 years," he says. To help API stay at the forefront of the terahertz industry, the company is continuing work with NASA through SBIR contracts with Glenn Research Center. The goal of this partnership is a computed axial tomography time-domain terahertz system capable of creating three-dimensional images.

"There has been great collaboration between API and NASA," says Williamson. "NASA has helped us push the envelope." ❖

Smart Sensors Assess Structural Health

Originating Technology/NASA Contribution

The materials used to make airplanes and space shuttles do not last forever. That is why NASA frequently inspects launch vehicles, fuel tanks, crew habitats, and other components for structural damage. The timely and accurate detection of cracks or other damage can prevent failure, prolong service life, and ensure safety and reliability.

The Composite Crew Module (CCM) is a full-scale test version of the Orion spacecraft. As seen here, the CCM has fiber optic and traditional strain gauges attached.

To perform quick, nondestructive evaluation and monitoring of aerospace vehicles and structures, NASA pursues the development of structural health monitoring (SHM) systems. SHM aims to build a system with a network of sensors placed in critical areas where structural integrity must be maintained, such as vehicle stage sections, separation interfaces, solid motors, and tanks. The sensors send information to a computer that is programmed to recognize patterns of electrical signals that represent damage, such as strains, breaks, or cracks. These systems can automatically collect and process data.

One approach to SHM is the Stanford Multi-Actuator Receiver Transduction (SMART) Layer, a patented technology from Stanford University. The thin material layer is embedded with a network of piezoelectric sensors and actuators that can be mounted on metal structures or embedded in composite structures. The piezoelectric sensors give off a small amount of electricity when they undergo mechanical pressure. Similar to a medical ultrasound, the sensors generate a wave that propagates through the structure and is picked up by other sensors. The aim is not only to detect structural damage, but to provide early warning before a failure takes place.

To enhance and commercialize the SMART Layer, Acellent Technologies Inc. was founded in 1999 in Sunnyvale, California. Soon after its founding, the company created an SHM system consisting of the SMART Layer, supporting diagnostic hardware, and data processing and analysis software.

Partnership

In 2001, Acellent started working with Marshall Space Flight Center through a **Small Business Innovation Research (SBIR)** award to develop a hybrid SMART Layer for aerospace vehicles and structures. The hybrid layer utilized piezoelectric actuators and fiber optic sensors. As a result of the SBIR, the company expanded the technology's capability to utilize a combination of sensors for various applications, such as monitoring strain and moisture.

A development known as the hybrid piezoelectric/fiber optic structural diagnostics system was intended to perform quick nondestructive evaluation and longer-term health monitoring of aerospace vehicles and structures, and could potentially monitor material processing, detect structural defects, detect corrosions, characterize load environments, and predict life. Piezoelectric actuators were embedded along with fiber optic detection sensors including Fabry-Perot fiber optic strain gauge sensors and fiber Bragg grating sensors.

Additional SBIRs with Marshall helped Acellent to improve and optimize its technology. The SMART Suitcase was developed and used for testing the SMART Layer and other SHM technologies. A NASA Space Act Agreement through Marshall investigated radio frequency attenuation transmission and detection using the SMART Layer approach. Marshall also provided knowledge advancement through testing opportunities with composite over-wrapped pressure vessels, which were being developed and studied for potential use in several space programs. Under a 2004 SBIR, Acellent tested and evaluated the performance of a SMART Tape, based on the SMART Layer, in harsh cryogenic conditions.

"We used the same base technology in all of the SBIRs, but for different applications requiring new innovations. This increased the reliability of the system and made it more robust," says Shawn Beard, chief technology officer at Acellent.

In 2009, Acellent's SMART Layer technology won the "Best Practical SHM Solution in Aerospace" award at the International Workshop on Structural Health Monitoring, sponsored by the Airbus Company. Twelve organizations participated in the competition, which was judged by representatives from industry, universities, and government agencies.

Beard attributes the technology's competitive advantage to the knowledge gained while working with

Marshall. "There are other technologies that are being applied for SHM, but they are behind in development of a complete system. There was a lot of testing and improving the technology over the last decade under the SBIR program to optimize the system," says Beard.

In 2009 and 2010, Marshall supported the implementation and testing of the Acellent pitch-catch piezoelectric sensor on the Composite Crew Module (CCM) for the Ares Program. The CCM is a full-scale test version of the Orion spacecraft.

Product Outcome

Acellent develops advanced active and passive diagnostic systems using built-in networks of actuators and sensors.

Customarily, SHM uses sensors and actuators arrayed at various locations on a structure. In contrast, the SMART Layer contains an entire sensor and actuator array, making it unnecessary to install each sensor and actuator individually. The SMART Layer is pre-networked and pre-positioned, making it very easy for installation. The layer can be mounted on an existing structure or integrated into a composite structure during fabrication. Different types of sensors, such as piezoelectric and fiber optic, can both be embedded in the sheet to form a hybrid network.

Capable of being integrated into new or existing structures, SMART Layer technology is used to automate inspection and maintenance including structural condition monitoring, load and strain monitoring, impact detection, damage detection, impact damage assessment, crack growth monitoring, debonding detection, process monitoring, materials cure monitoring, and quality control.

The main benefits of SMART Layer technology are its flexibility, light weight, ability to adapt to any structure, ease of installation, durability, and reliability under different environments. The size and shape of the technology varies, and Acellent manufactures SMART Layers in numerous sizes, shapes, and complexities—from single sensor flat strip to multisensor 3-D shells. In addition to the sensor network, Acellent provides the diagnostic hardware and data analysis software for different SHM applications from monitoring large composite structures to localized damage detection in composites and metals.

Acellent's SMART Layers can be customized with two or more sensors in a strip unit, like the eight-sensor strips shown here, to monitor structural health conditions such as strain and moisture.

Acellent has been funded to monitor civil infrastructure such as pipelines, buildings, and bridges.

According to Acellent, customers and partners include aerospace and automotive companies; construction, energy, and utility companies; and the defense, space, transportation, and energy industries. Private and government research labs have purchased the technology to gauge its performance in particular environmental conditions.

Acellent has had sales contracts with many major aerospace companies, including Boeing, Lockheed-Martin, Bombardier, and Airbus. Acellent is also customizing the technology for the U.S. Army to monitor fatigue cracks in rotorcraft structures. Recently, BMW used the SMART Layer technology on a concept vehicle to help verify the design and modeling, and to improve manufacturing techniques.

Over the last couple of years, Acellent has been funded to monitor civil infrastructure such as pipelines, buildings, and bridges, including a recent project with the National Institute of Standards and Technology. "We have been asked to develop a system—not just to monitor damage to a structure—but to monitor the overall framework or architecture for monitoring bridges across the Nation," says Beard.

In addition to winning sales for research and testing, the company has won additional NASA SBIRs to apply the technology to large scale structures like rocket motors. Acellent's long-term goal, however, is to have the technology become part of the design process. Instead of applying SHM after a new spacecraft is designed, Beard says the company envisions SHM being included in the original design of the structure. "If you design sensors into the structure in the beginning, you can optimize the structural design and reduce the overall weight of the vehicle. That is the direction we would like to see the technology go." ❖

Burnishing Techniques Strengthen Hip Implants

Originating Technology/NASA Contribution

When compressed air mixes with jet fuel and is ignited in a turbine engine, the temperature can reach 3,000 °F. As a result of this fiery exhaust, the turbine spins and then forces the air through the back of the engine, and the jet moves forward. While extremely hot air assists in propelling a plane, it can also take a toll on the turbine blades and propeller hubs.

An engine component's lifespan is limited not only by heat, but also by general fatigue (weakening), corrosion, fretting fatigue (mechanical wear and oxidation that leads to cracking), and foreign object damage. Even a small amount of damage can cause a failure that can result in catastrophic consequences. Inspection and maintenance to avoid these failures in aerospace turbine engines is estimated to cost billions of dollars annually.

Techniques such as shot peening (impinging small steel spheres on a surface), laser shocking (using a laser to apply shock waves to a material), and deep-rolling (applying force by rolling a tool over the surface) are often used to apply compressive residual stress that actually boosts the strength of tough metal engine components.

In the 1990s, when NASA was looking for new and improved methods to increase the lifespan of engine components that undergo extreme temperatures and service, it found an alternative process called low plasticity burnishing (LPB), developed by Lambda Research Inc., of Cincinnati, Ohio.

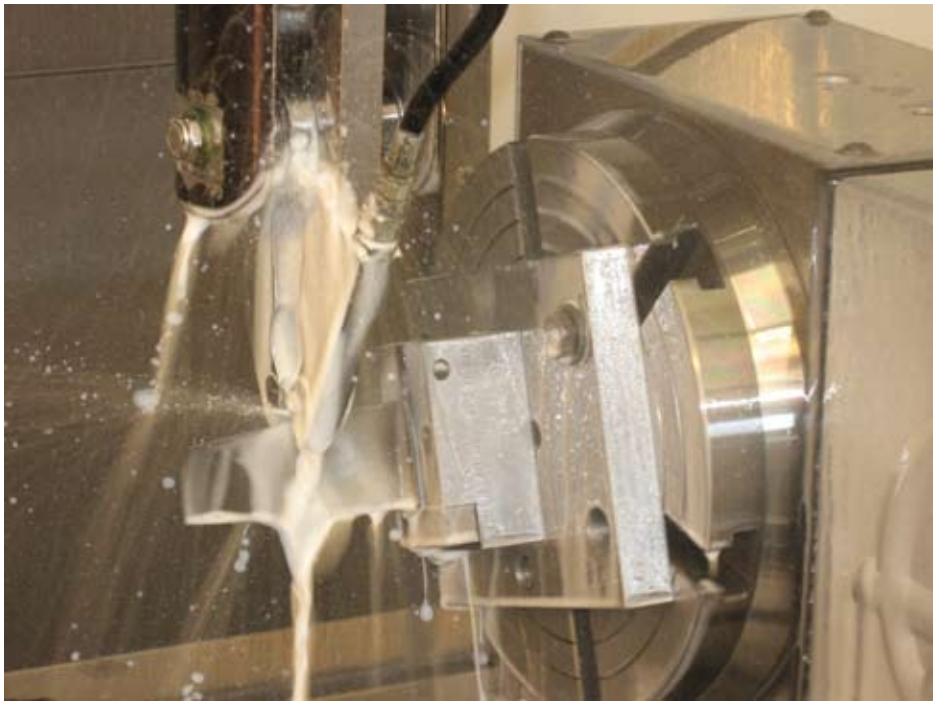
Based on a series of studies on the thermal stability of a variety of surface treatments including shot peening and laser shocking, Lambda discovered that the more cold work (working of metal at room temperature) a material underwent, the less strength it retained when subjected to high temperatures. In developing LPB, Lambda used only a fraction of cold working, which increased the damage tolerance of materials and prevented cracking in components designed for high-temperature situations.

Partnership

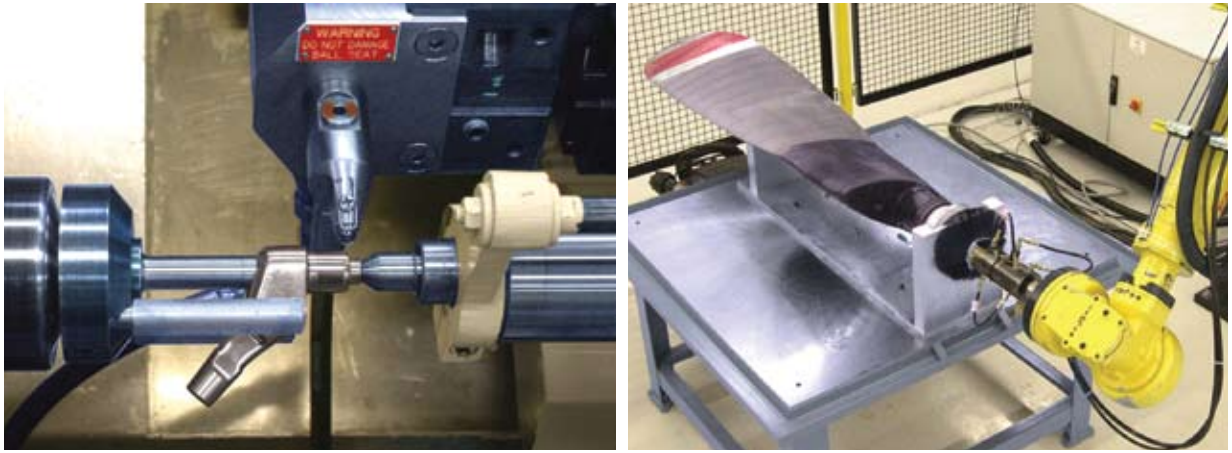
To demonstrate LPB in the hot sections of turbine engine metal components, NASA's Glenn Research Center awarded Phase I and II **Small Business Innovation Research (SBIR)** contracts to Lambda in the late 1990s. Through these SBIRs, Lambda showed LPB to be an affordable means of producing a thermally stable deep layer of compressive residual stress in metallic components that remained stable at engine operating temperatures. LPB also increased the lifespan of components, doubled the endurance limit of components, halted existing cracks, and improved the fatigue performance of turbine alloys without altering the alloy or the design.

Performed by rolling a hydrostatic bearing tool over the surface of a specific part or piece, LPB allows an exact amount of force to create a desired layer of compression in one pass. By producing a repeatable and stable deep layer of compressive surface residual stress, metals become more resistant to corrosion, damage from foreign objects, and cracking.

"NASA gave us the initial opportunity to demonstrate LPB in an application that provided the new technology to the aircraft engine, ground-based turbine applications, and to aging aircraft. The initial NASA SBIR was also instrumental in supporting additional, more extensive funding that was available through the Department of Defense, primarily with the Naval Air Systems Command (NAVAIR) and some with the Air Force, which has led to the introduction of LPB into commercial aircraft, now with the support of the Federal Aviation Administration (FAA)," says Paul Prevéy, CEO of Lambda Technologies Group.



Developed by Lambda Research Inc. and refined with NASA's Glenn Research Center's funding, low plasticity burnishing (LPB) strengthens metal components, like the F100 aircraft blade shown here, by applying force to the surface of a material to produce a desired layer of compressive residual stress. The technique has proven effective for components that undergo extreme pressure, temperature, and stress.



The LPB process completely eliminated the occurrence of fretting, which leads to cracking, in the neck segment of a medical hip implant (above left). It also increased the fatigue strength of the implant by 40 percent and the lifespan by more than 100 times. Performed in a machine shop environment, in the field, and by using industrial robotic tools (above right), LPB can be applied to new or old metal components.

Prior to completing its work with NASA, Lambda patented the LPB process and created a spinoff company, Surface Enhancement Technologies LLC, to market LPB. In 2010, LPB earned recognition as one of the "R&D 100" (a list of the top 100 inventions of the year), granted by *R&D Magazine*.

Product Outcome

Capable of being applied to all types of carbon and alloy steel, stainless steel, cast iron, aluminum, titanium, and nickel-based super alloys, and many components with odd shapes or forms, LPB can be performed in a machine shop environment, in the field, and by using robotic tools. One important feature of the LPB application method is that it is highly controllable and can be validated to ensure that the process is applied to every part.

Over the last decade, LPB has been successful in completely eliminating fatigue failures in the first stage vanes on aircraft engines. Previously, these failures had resulted in the loss of several aircraft and crew. Lambda has processed over 45,500 of these vanes, and achieved process control exceeding Six Sigma. This processing is what led to FAA acceptance of LPB as a suitable process for both repair and alteration of commercial aircraft components. It is estimated that LPB will save the aircraft market over $10 million for the mitigation of stress corrosion cracking on just one landing gear application.

In 2009, Lambda and Delta Airlines announced an exclusive partnering agreement to use LPB for maintaining commercial aircraft components such as landing gear, propeller hubs, and turbine engine blades. According to the companies, the team effort provides opportunities to extend the life of aging aircraft, overcoming damage from foreign objects, stress corrosion cracking, and corrosion pitting damage mechanisms that are common throughout the commercial aircraft fleet.

In addition to having a significant impact on defense and aerospace components, LPB has also had a major impact on medical implant manufacturers. Lambda finds the savings for the medical and aircraft markets combined could reach numbers in excess of $100 billion.

A 2004 partnership between Lambda and Exactech, an orthopedic company that develops, manufactures, markets, distributes, and sells orthopedic implant devices and related surgical instrumentation, initiated the first commercial application of LPB to stop fretting in medical implants. Prior to working with Exactech, Lambda addressed a similar problem under SBIRs with NAVAIR, building on the work of NASA SBIRs, to apply LPB to stop fretting damage on the blade dovetail joint on jet engines.

In the case of the hip implant, fretting was occurring in a section of the hip stem due to severe cyclical stress, as every step taken by a patient represented a single loading and unloading cycle. Exactech explored a number of solutions to increase the performance of the implant, including laser peening and roller burnishing, but nothing compared to LPB, which improved the fatigue strength of the hip stem by more than 40 percent and increased the lifespan of the piece by more than 100 times. Data from the U.S. Food and Drug Administration confirmed that LPB completely eliminated the occurrence of fretting fatigue failures in modular hip implants. LPB has been integrated in the manufacturing process and applied to more than 3,400 hip implants.

Another application where LPB was chosen over laser peening was in eliminating residual tension in the final closure weld of the long-term nuclear waste storage containers for Yucca Mountain. The design review board for the containers unanimously selected LPB for the greater depth of compression, advantages in logistics, quality control, surface finish, and cost. The U.S. Department of Energy found LPB produced residual compression that exceeded the depth required for the surface to remain in compression for the 50,000-year design life of the containers. ❖

Do-It-Yourself Additives Recharge Auto Air Conditioning

Originating Technology/NASA Contribution

Even though it drops to -279 °F at night and dips to -400 °F inside its deepest craters, the Moon can reach a scorching 260 °F during the day. The range of temperatures is extreme—in part because there is no substantial atmosphere on the Moon to insulate against the heat or cold. What the Moon does have are small amounts of gasses above its surface, sometimes called a lunar atmosphere or exosphere, that consist mostly of hydrogen and helium, along with some neon and argon.

On Earth, traces of an atmosphere extend as high as 370 miles above the surface. Made of 78-percent nitrogen and 21-percent oxygen, 1 percent of Earth's atmosphere consists of argon and other gasses—some of which help to trap heat from the Sun and create a greenhouse effect. Without this effect, Earth would probably be too cold for life to exist. Another helpful feature of the Earth's atmosphere exists about 30 miles above the surface, where ultraviolet light from the Sun strikes oxygen molecules to create a gas called ozone. This ozone blocks harmful ultraviolet rays from reaching the Earth.

In planning for a return mission to the Moon, NASA sought to improve the thermal control systems that keep astronauts comfortable while inside a spacecraft like the Lunar Module "Eagle," shown here on the far right.

While the Earth's atmosphere protects and defends against extreme temperatures like those on the Moon, Earth's heating and air conditioning systems create an even more comfortable atmosphere indoors. In planning for a return mission to the Moon, NASA aimed to improve the thermal control systems that keep astronauts comfortable and cool while inside a spacecraft.

Partnership

In the late 1990s, Goddard Space Flight Center awarded a **Small Business Innovation Research (SBIR)** contract to Mainstream Engineering Corporation, of Rockledge, Florida, to develop a chemical/mechanical heat pump as part of the spacecraft's thermal control system. Designed to transfer heat from one location to another, a heat pump provides cooling by moving heat out of one area and into another. While working on the heat pump design at Goddard, Mainstream Engineering came up with a unique liquid additive called QwikBoost to enhance the performance of the advanced heat pump design.

Previously featured in *Spinoff* 1999, QwikBoost circulates through a system like a lubricant, working to boost the available cooling capacity. This increases the performance of the system and results in faster heat transfer (cooling) and consumption of less operating energy.

After Mainstream Engineering patented the QwikBoost technology developed with NASA, it started manufacturing and selling the additive to improve the operating efficiency and economy of refrigeration systems, air conditioners, and heat pumps. NASA used QwikBoost to develop more efficient, smaller, and lighter cooling systems, as well as in air conditioning and refrigeration systems at NASA facilities, and in air conditioning systems in NASA's vehicle fleet.

"Working with NASA technology bolsters our confidence that the chemistry has been thoroughly tested and proven."

Recognizing the capabilities of QwikBoost, a New York-based company, Interdynamics Inc., exclusively licensed the additive from Mainstream Engineering in 2004. As a developer of do-it-yourself air conditioning recharger kits, Interdynamics soon merged with EF Products Inc., of Dallas, Texas, a provider of closed system retrofit kits for automotive air conditioning systems, to become IDQ Inc., of Garland, Texas, with sales and marketing out of Tarrytown, New York. Today, IDQ incorporates the NASA-derived QwikBoost technology into its line of Arctic Freeze products.

According to the company, by using Arctic Freeze to replace lost refrigerant and oil in an automotive air conditioning system, the NASA-derived QwikBoost chemistry provides colder air up to 50-percent faster than a conventional R-134a refrigerant product. "Working with NASA technology bolsters our confidence that the chemistry has been thoroughly tested and proven to deliver the benefits and results promised," says Vincent Carrubba, director of research and development at IDQ.

Product Outcome

IDQ provides a variety of automotive air conditioning products for the do-it-yourself consumer and professional service technician, including its line of Arctic Freeze products. Sold at leading automotive and mass-retail stores and through wholesale distributors in the aftermarket industry in the United States, Europe, and Latin America, Arctic Freeze restores cooling in a vehicle's air conditioning system once the system is no longer cool-

IDQ Inc.'s Arctic Freeze-1 product recharges the air conditioning in most passenger automobiles manufactured after 1995. It comes with step-by-step instructions, a built-in reusable installation hose, snap-on coupler, and air conditioning pressure gauge.

The full line of Arctic Freeze products incorporates a QwikBoost refrigerant enhancer originally developed by NASA and Mainstream Engineering Corporation, of Rockledge, Florida. According to IDQ, QwikBoost provides vehicle owners with colder air up to 50-percent faster than a conventional refrigerant product.

ing effectively or when the performance has degraded to blowing only warm air. The product replenishes a system with R-134a containing the QwikBoost synthetic refrigerant enhancer.

Compared to operating with only PAG-oil (a lubricant), the addition of QwikBoost reduces wear and tear on the system by lowering compressor temperatures and extending the useful life of the lubricant. Arctic Freeze also incorporates a system-safe leak sealer that conditions rubber o-rings, seals and hoses, which are the primary source of minor system leaks.

In addition to delivering low vent temperatures, Arctic Freeze also delivers low costs. Depending on which Arctic Freeze product a customer uses, recharging an automotive air conditioning system can cost approximately $15–$30, compared to $100 or more at an automotive repair shop. Each Arctic Freeze product provides do-it-yourself customers with everything needed to recharge a vehicle air conditioning unit.

Carrubba believes NASA technology has made a world of difference by providing a demonstrable and affordable solution to improve the efficiency and economy of operating air conditioning and refrigeration systems here on Earth. "The all-in-one solutions of Arctic Freeze make it possible for nearly anyone to safely, effectively, and affordably recharge their own vehicle's air conditioning unit." ❖

Personal Aircraft Point to the Future of Transportation

Originating Technology/NASA Contribution

In the late 1970s, general aviation (GA) in the United States was experiencing its heyday. In 1978, as many as 18,000 GA aircraft were produced. But only 15 years later, the industry was on the verge of collapse, with fewer than 1,000 aircraft produced in 1993.

One of the reasons for this decline was the lack of technological development that exposed the industry to safety and efficiency concerns. NASA, however, saw great potential within the GA industry to revolutionize the U.S. transportation system. With congestion growing both on the roads and in the skies, the Agency envisioned a Small Aircraft Aviation System, or SATS, in which improved GA aircraft would serve as an efficient travel option for round-trip distances too long to comfortably drive but too short to be practical for regular commercial airline service. Making use of the Nation's 19,000 airports (of which 14,000 are privately operated), SATS would provide an alternative to crowded highways and the overburdened hub-and-spoke airline system.

In order to facilitate the creation of SATS, GA aircraft needed to become cheaper to produce, quieter and more fuel efficient, and easier and safer to fly. In 1994, NASA and the Federal Aviation Administration (FAA) joined with private industry, academia, and nonprofits to form the Advanced General Aviation Transport Experiments (AGATE) consortium. Consisting of about 70 members

Originally built to allow Apollo astronauts to practice landing on the Moon, this 240-foot-high gantry (left) is now Langley Research Center's Landing and Impact Research Facility. Crashworthiness testing at the facility (right) allowed Cirrus Design Corporation to improve survivability during stall/spin impacts.

and led by NASA's Langley Research Center, AGATE sought to revitalize the GA industry and help drive the technological innovation needed to make SATS viable. Among the technologies AGATE focused on were safety and crashworthiness improvements, guidance systems, aerodynamically efficient airfoils, and manufacturing processes.

While AGATE ended in 2001, NASA continues to inspire the GA industry through efforts like the upcoming 2011 Green Flight Challenge, which seeks to demonstrate personal aircraft featuring maximized fuel efficiency, improved safety, and reduced noise. In the meantime, innovations with origins in the AGATE program continue to shape general aviation today.

Cirrus' synthetic vision systems trace their roots to innovations in glass cockpit technology developed under the NASA-led Advanced General Aviation Transport Experiments consortium.

Partnership

Among the primary tools AGATE employed to stimulate innovation and technology transfer were the **Small Business Innovation Research (SBIR)** and **Small Business Technology Transfer (STTR)** programs. Companies that received Phase II SBIR or STTR contracts were invited to join the AGATE consortium, further encouraging collaboration among government, academic, and industry partners.

One such company was Cirrus Design Corporation, based in Duluth, Minnesota. Founded in 1984, Cirrus' first product was an experimental aircraft, the VK-30. The company was keen on improving personal aircraft performance by making use of natural laminar flow; vehicles that take advantage of this property experience significantly less drag and thus fly faster and with better fuel efficiency. The VK-30 featured a natural laminar flow airfoil (the NLF-414F) designed by Langley engineer Jeff Viken. The problem with manufacturing the airfoil, however, was that production methods that used aluminum to craft the wing ultimately destroyed the laminar flow properties of the airfoil.

Through SBIR contracts with Langley, Cirrus worked on developing low-cost manufacturing methods using composite materials, which would provide a strong, lightweight aluminum alternative that preserved natural laminar flow. At the time, composites were used either for boats or for high-end military aircraft, says Cirrus chief engineer, Paul Johnston.

"We needed the composites to be aerospace quality but more in line cost-wise with what it would take to make a boat," he says. Cirrus' SBIR work resulted in significant composite manufacturing expertise and a pre-impregnated composite that could be readily mass-produced.

Additional SBIR work with Glenn Research Center explored electroexpulsive deicing systems to help ensure safe operation in dangerous icing conditions. While this technology ultimately proved commercially impractical for Cirrus, the company developed a method under the SBIR for mating the system to aircraft wings without disrupting their natural laminar flow. Cirrus later applied the same method to install glycol "weeping wing" systems, providing chemical icing protection without sacrificing performance.

Product Outcome

Cirrus employs both of these SBIR-derived benefits in the production of its industry-leading aircraft today. The Cirrus SR20 and the faster, more powerful SR22 and SR22 TURBO personal aircraft are currently among the most popular GA aircraft in the world; the SR22 has been the top-selling FAA-certified single-engine airplane every year since 2002.

Among the features that have earned Cirrus planes such popularity are a host of innovations with NASA

Featuring a host of NASA-derived design and technology features—including an additional NASA spinoff, the standard Cirrus Airframe Parachute System manufactured by BRS Aerospace Inc.—the Cirrus SR22 is the top-selling FAA-certified single-engine airplane in the world.

The Cirrus SR20 benefited from low-cost composite materials manufacturing that Cirrus developed through SBIR contracts with Langley.

connections. Perhaps the most important are the comprehensive safety features. GA aircraft typically fly at too low of an altitude to recover from a spin in time to avoid impact. NASA researchers in the 1970s and '80s focused on methods to help prevent aircraft from getting into a spin in the first place. Cirrus now employs a NASA-designed "drooped" leading edge on its airfoils that lowers stall speed and greatly increases spin resistance. In addition, through crashworthiness testing in the late 1990s—using Langley's Landing and Impact Research Facility, a 240-foot-high gantry originally built to train Apollo 11 astronauts for their historic Moon landing—Cirrus incorporated design features to improve survivability during stall/spin impacts.

"We also tested airbags," says Johnston. "There were no such thing as airbags in airplanes at the time, and now that's an option on all of our planes." Cirrus offers AmSafe Aviation Inflatable Restraints—seatbelt airbags—and was the first aircraft manufacturer to install the devices.

Another major safety feature is the Cirrus Airframe Parachute System, a whole-aircraft parachute capable of rescuing not only the pilot and passengers, but the entire plane. Invented by BRS Aerospace Inc. with NASA SBIR support (*Spinoff* 2002, 2010), the technology is standard on all Cirrus aircraft and has saved 35 Cirrus pilot and passenger lives to date.

Also key to enhancing safety are innovations that make Cirrus planes easier to fly.

"The AGATE program looked at how to take the essential information pilots need and display it to them in a manner that is intuitive and easy to use," says Johnston. One of AGATE's major contributions was the advancement of glass cockpit technology. (This does not refer to an airplane's windows. Rather, a "glass cockpit" features electronic instrument displays.) Among these technologies were synthetic vision systems that create three-dimensional renderings of the environment outside the aircraft, helping a pilot navigate, read the terrain, identify obstacles, and negotiate airborne traffic. One synthetic vision feature was the "Highway in the Sky," or HITS, a technology developed by avionics company Avidyne under a NASA contract. HITS simplified navigation by displaying boxes on the aircraft's screen that the pilot can (virtually) fly through—much like a video game. All of Cirrus' aircraft incorporate this technology, either through an Avidyne system or the new Cirrus Perspective synthetic vision system.

"This technology presents the pilot with the information necessary to fly without requiring the massive amounts of training and proficiency needed with the previous instrumentation," says Johnston. "It becomes easy to take on flight tasks that were once only for the highest experts."

The company's latest venture represents the newest wave of GA aircraft: the very light jet, or VLJ. Cirrus is developing its Vision personal jet, which the company promises will be lighter, quieter, and more efficient than other personal aircraft—another step toward making SATS a viable reality. The Vision is powered by the FJ33 turbofan engine, developed by engine manufacturer Williams International as part of the General Aviation Propulsion project, representing yet another legacy of the NASA-led AGATE program.

"NASA plays a role in looking at the transportation infrastructure as a whole and figuring out how to make it as efficient as possible to serve the most people with the least amount of resources," says Johnston.

"I don't think much of what you see in general aviation today would be around if NASA had not laid the foundation." ❖

Powered by a turbofan engine designed as part of the NASA General Aviation Propulsion project, the Cirrus Vision jet promises to provide the kind of quiet and efficient flight option that could make such vehicles viable, commonplace options for personal travel in the future.